Management, Economics, and Animal Welfare Characteristics of Large Dairy Operations in the Upper Midwest

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Dedication

This thesis is dedicated to my late father, Kevin Evink, who passed away in the fall of 2008 after a brief battle with cancer. Without the work he did and sacrifices he made for our family growing up, or his constant guidance and support, I would not be where I am today. The patience, work ethic, humility, and compassion for others he possessed were unlike any other, and it is through those values that have been instilled in me that I try to live my life each day.

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INTRODUCTION

The US dairy industry has undergone significant changes in recent decades. Most notably, farms continue to get larger while the overall number of dairy operations continues to decrease. Dairy farms today are complex systems that require meticulous management and integration between each of its parts to be successful. This concept is even more apparent in the industry today, meaning that as farms do continue to increase in size, it is important to understand how these systems work to ensure their sustainability in future generations.

The objective of this study is to characterize management practices, economics, and animal welfare in large dairy operations in the Upper Midwest. The first chapter is a review of literature focused on the changing structure of the US dairy industry and the driving forces behind these changes. Along with this, management and housing systems, factors related to animal health and well-being, and economic characteristics affecting the industry will be discussed. The aim of chapter 2 is to provide a description of common management practices and animal welfare characteristics of dairy operations with more than 2,500 cows in the Upper Midwest. In addition, risk factors in these operations for certain animal welfare characteristics will be analyzed and discussed. The third chapter will work to describe economic and operational characteristics of the large dairy operations that were presented in chapter 2. Within this, specific management practices and animal welfare information will be described for higher and lower profitability farms to be able to identify characteristics of those different groups.

CHAPTER 1:

Literature Review - Previous Work on Demographic, Structural, and Management Trends in the Dairy Industry that Affect Cow Welfare and Productivity

INDUSTRY TRENDS

Background

Over the past century, the dairy industry has undergone significant structural and technical changes in how and where milk is produced. Up until the time of the mid-20th century, dairy farming was largely done as a sideline activity of the small, self-sufficient farming operations that were found all across the countryside. Right around that time, however, there were a number of changes that occurred that helped to shape the industry to where it is today. The changes that occurred fall under one of three categories: technological innovations, changes in the milk production system, and specialization. (Blayney, 2002)

Technological innovations not only revolutionized the way that dairy farming was able to be performed, but it also changed the way all sectors of agriculture were able to operate. The development of on-farm machinery allowed farmers to substitute mechanical equipment for human labor, leading to an increased efficiency in producing milk (Blayney, 2002). Equipment like mechanical milking machines, feeding systems, and waste handling systems all played a major role in improving labor efficiency, and this continues today with the continued development of computerized monitoring tools for precision dairy management.

Along with these many innovations, there was also a great change in the system from which milk was produced. Up until this time dairies were largely pasture-based systems; however, a shift occurred that saw an industry-wide change to the development of confinement feeding systems (Blayney, 2002). This shift in the production system allowed producers to focus solely on cow management. Factors like nutritional quality and genetics received a greater emphasis, which in turn led to an increase in milk production per cow and a decrease in production costs. From this, farmers began to take advantage of economies of scale for the first time, and milk production began shifting from local production to a more national and global scale (MacDonald et al., 2007).

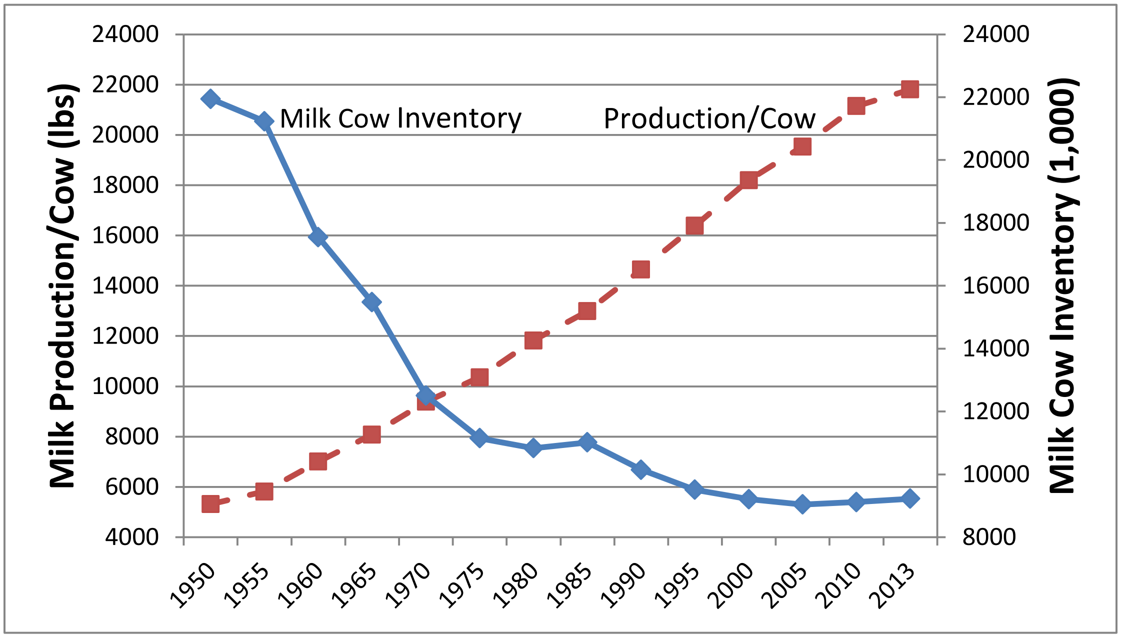
The last of main factors that led to the changing structure of the dairy industry was the development of specialization. Farms were historically diversified, self-sufficient operations where milk production was largely viewed as a sideline activity to other types of livestock and crop production. With this shift in the production system that allowed for improvements in milk production and decreased production costs, dairy farming shifted from a sideline activity on the farm to the sole or most important activity. Farmers also shifted their responsibilities from a do-it-all type of worker to one that specialized in singular aspects of the farm (Blaney, 2002). Because of the ability to hire outside labor to perform tasks like milking or working with cows, farmers would not necessarily need to be in the barns, and as a result of this some transitioned to the role of business or financial managers on the farm operation. This type of structure is becoming more and more common in today's dairy industry.

Farm Structure and Milk Production

With the changes that have occurred in the structure of the dairy industry over the past 60 years, the number and size of farms in operation today has been greatly affected. In 1950, there were over five million total farms and 68.3 percent, or just over 3.5 million of those farms had milk cows (USDA, 1956). At that time, the number of dairy cows in the country was over 21 million, resulting in an average of approximately six cows per farm. For the following 40 years, the number of dairy operations and the number of cows declined steadily. In 1990, there were just more than 10 million cows on 193,790 farms with an average herd size of 52 cows (USDA, 1991).

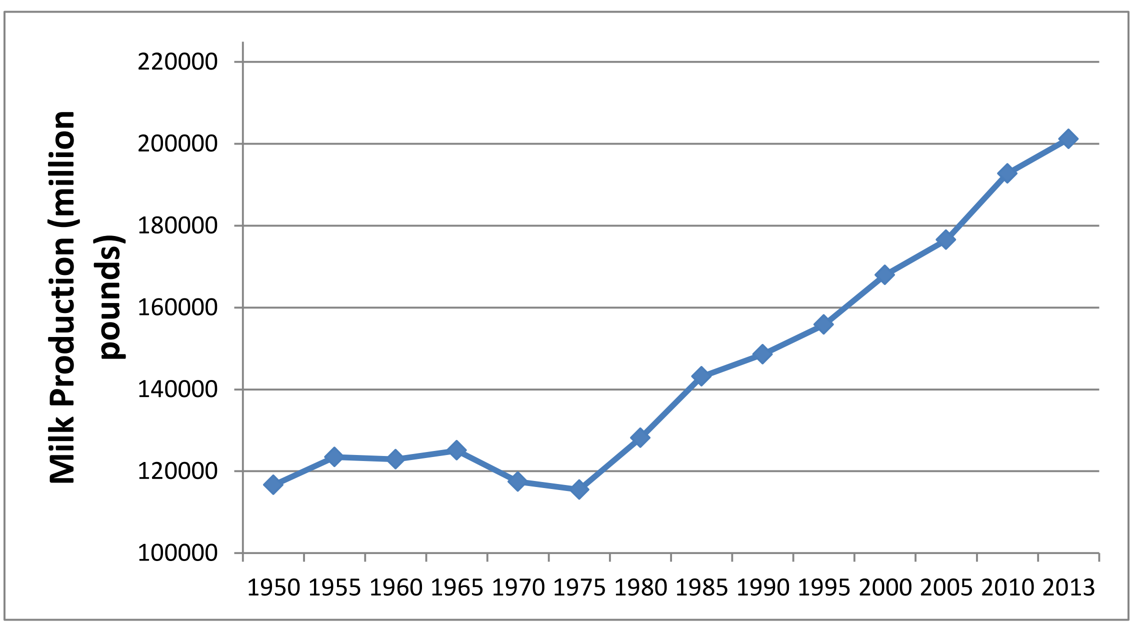
During the same time period, the level of milk production and efficiency in which cows were able to produce milk was also greatly impacted by the changing structure of the industry. Specialization allowed for improvements in nutritional quality and cow management. That in turn led to increases in milk production per cow and overall milk production. Figure 1-1 shows a graph of milk cow inventory and milk production per cow from 1950 to 2013.

Figure 1-1 Cow Inventories and Production per Cow, 1950-2013



Source: USDA, National Agriculture Statistics Service

Figure 1-2 U.S. Milk Production, 1950-2013



Source: USDA, National Agriculture Statistics Service

Figure 1-1 clearly illustrates the declining cow numbers, but it also shows the steady advancements that were made in improving production per cow over the past 60 years. Figure 1-2 illustrates the impact that the decreasing number of cows and increased production per cow has had on total milk production. Until 1975, production appeared to be stable. That is, increased efficiency in production per cow was able to offset the significant losses in milk cow inventory. After 1975, however, it appears that the rate at which milk cow inventory began to decrease slowed down, and in the past fifteen years the number of cows has stabilized between nine and ten million. During that time, milk production per cow continued to increase, which led to the steady increase in total milk production shown in figure 1-2.

While milk cow inventories have leveled off in their historically decreasing trend, the total number of dairy operations has continued on the path of steady decline. In turn, this has led to an increasing number of cows per farm. In 1990, there were approximately 200,000 dairy operations in the United States, whereas in 2012 that number fell to fewer than 50,000 operations that were licensed to sell milk (USDA, 2013). With the stabilization in milk cow inventory that was discussed above, average herd size has increased to 187cows per farm (USDA, 2013).

One other factor that has changed, along with the number and size of farms, is the size of the farms where a large majority of the cows are being held. Although average herd size in 2012 was just under 190 cows, operations that contained 199 cows or fewer accounted for just 28% of the total milk cow inventory, but represented 89% of the total number of operations (USDA, 2014) The largest of the groups, those farms with more than 2500 cows, accounted for just under 1% of the total number of milk cow operations. Yet, those farms represented almost 30% of the total milk cow inventory and total milk production in the country (USDA, 2014).

Demographics of U.S. Dairy Production

The location of where dairy operations are located has also gone under tremendous change in recent years. Historically, farms were located near large population centers in the Eastern and Midwestern United States. However, factors such as economies of scale, reduced transportation costs, population growth, and environmental concerns and regulations have brought about a shift in where milk is produced (MacDonald et al., 2007; Blaney, 2002). Table 1-1 shows the changes in the top ten milk producing states.

Table 1-1 United States Milk Production State Rankings: 1975 and 2013

	1975				
Rank	***State***	***Milk Production (million pounds)***	***Number of Cows (1,000 cows)***	***Average Herd Size***	***Share of U.S. Production (%)***
1	WI	18,900	1,812	34	16.4
2	CA	10,853	800	148	9.4
3	NY	9,904	917	43	8.6
4	MN	8,946	884	26	7.7
5	PA	7,140	699	28	6.2
6	MI	4,434	420	35	3.8
7	OH	4,254	400	26	3.7
8	IA	3,916	399	21	3.4
9	TX	3,221	335	22	2.8
10	MO	3,021	306	14	2.6
	2013				
Rank	***State***	***Milk Production (million pounds)***	***Number of Cows (1,000 cows)***	***Average Herd Size***	***Share of U.S. Production (%)***
1	CA	41,256	1,780	1,175	20.5
2	WI	27,572	1,271	117	13.7
3	NY	13,469	610	121	6.7
4	ID	13,431	573	1,042	6.7
5	PA	10,565	533	74	5.3
6	TX	9,610	437	950	4.8
7	MI	9,164	380	187	4.6
8	MN	9,140	464	120	4.5
9	NM	8,057	323	2,307	4.0
10	WA	6,336	262	546	3.1

Source: USDA, NASS *Milk Production,* Monthly Reports; Feb 11, 1976 and Feb 20, 2014.

Over the roughly 40-year period from 1975 to 2013, there was a large expansion of dairy farms in the West and Southwest regions of the United States. This is reflected in the table with the increased production in both California and Texas, as well as the addition of Idaho, New Mexico, and Washington to the rankings. Operations in these areas tend to be larger, with average herd sizes near 1,000 cows. Because of this, the share of total production from Western and Southwestern states in the rankings has grown to be almost 40%, compared to 1975, when these states held just over 10% of the total production share.

While large farms dominate the regions of the West and Southwest, the structural change in the sizes of farms is not limited to those regions. In the traditional dairy states of the Northeast and Midwest, where milk production has historically come from smaller operations, there has been also an increase in large farms' share of milk production (MacDonald et al., 2007). Table 1-2 shows the share of milk production by herd size for selected states for the years 2000 and 2012. The trend over this 12-year period is glaring, especially in Midwestern states such as Minnesota, Wisconsin, Iowa, and South Dakota, where the share of milk production from larger farms (greater than 500 head) has increased threefold.

Table 1-2 Farm Structure in Select U.S. States

State	Herd Size			
	< 100 Head		500+ Head	
	2000	2012	2000	2012
	(Percent of State Production)			
Northeast				
NY	34.0	22.8	16.0	50.1
PA	63.5	49.8	3.0	15.0
VT	35.0	18.5	16.0	42.0
Midwest				
IA	56.0	20.0	5.0	44.1
MI	28.0	10.2	20.0	57.8
MN	59.5	29.3	8.5	32.6
SD	34.0	8.3	26.0	75.2
WI	56.0	26.4	9.0	38.1
Southwest				
NM	0.2	0.1	98.0	98.9
AZ	0.4	0.1	95.0	99.6
TX	7.0	1.8	47.0	89.0
West				
CA	0.6	0.3	78.0	93.9
ID	4.5	1.3	74.0	92.2
OR	8.0	2.5	39.0	73.7
WA	3.0	1.4	58.0	83.7

Source: USDA, NASS *Milk Production,* Feb 16, 2001 report (for 2000 data); USDA, NASS 2012 Census of Agriculture *State-level Data* (for 2012 data).

MODERN DAIRY OPERATIONS

Large dairy farms are set-up and operated in fundamentally different ways than the small farms that once dominated the industry. The main differences come in the form of labor and facilities. With the trends in increasing farm size, the majority of labor on dairy farms is now being provided by hired labor, usually of foreign origin, instead of an individual or an individual and their family. A recent study by Rosson et al. (2009) found that in a survey of 5,005 dairy farms in 47 states, 50% of dairy farms use immigrant labor. It was also estimated that 62% of the nation's milk supply comes from farms with immigrant labor, and of the estimated 138,000 full-time workers in the dairy industry, 41%, or 57,000, are of foreign origin (Rosson et al, 2009). Facilities too have undergone tremendous changes over the years, evolving from small pasture based or tie-stall systems that house a small number of cows to larger free-stall systems or dry lot dairies that contain a large number of cows in large pens or groups. These new facilities are far from being perfect; however, much attention has been put into research of these confinement facilities looking at how various building structures, ventilation systems, and bedding types affect the physical environment in which a cow lives.

Dairy Cattle Housing

Perhaps one of the most important aspects of facility design is the physical structure of the barn and the ability to provide the cow with a comfortable environment with access to feed and water. The ability of providing feed and water relies largely on human labor in respect to its delivery, so a large part of modern facility design is how to provide the most comfortable environment for cows in terms of keeping a supply of fresh air in the facility, providing a comfortable resting area, and maintaining ambient temperature to avoid the effects of heat or cold stress. Hahn (1985) found that minimal production losses occur when ambient temperature is maintained between -5 and 20˚C. Therefore, it should be the object of any housing system to maintain the animal in this environment to ensure optimal performance. In the Midwest, naturally ventilated freestalls and mechanically ventilated freestalls are the two most common barn types built for large-scale modern dairy production.

Naturally Ventilated Freestalls. Naturally ventilated freestall barns utilize wind as the primary source for ventilation, and are characterized by a continuous ridge opening, continuous sidewall and eave openings, and a roof slope with a pitch of 4/12 to 6/12 (Holmes et al., 2013). In larger herds in the Midwest, stalls are commonly configured in 2 rows or 3 rows per pen. The mechanism for air exchange and movement is provided by wind blowing through sidewall openings and indoor/outdoor temperature differences. Fresh air is able to enter through the eave or sidewall openings, forcing heat, moisture, or contaminant-laden air to exit through the continuous open ridge in the peak of the barn's roof, or it can also escape through the downwind sidewall opening on the opposite side of the barn (Holmes et al., 2013). For proper construction, barns should be placed on an area of high ground without any wind obstructions, and oriented in a manner for maximum summer wind exposure; in the Midwest, this usually results in an east-west orientation. Along with that, a ridge opening of at least 2 inches for every 10 feet of building width is considered optimal, and sidewall heights of 12 to 14 feet should be used for barns with drive through feed lanes (Holmes et al., 2013).

The main concerns with any naturally ventilated facility arise during periods of extreme cold or extended periods of warmer weather with little to no wind. Janni and Allen (2001) studied the dry bulb air temperature and relative humidity of three different curtain-sided naturally ventilated freestall barns located in Minnesota and Wisconsin. This was done for three weeks during three different months (January, March, and July) to represent times of cold, mild, and warm weather. They reported temperature inside the barns ranged from 2.0 to 8.6˚C warmer than the ambient air temperature during the week of cold in January, with average temperatures inside the barn ranging from -6.0 to -9.2˚C. This same study found that during the week of recording in July, however, the temperature inside the barns ranged from 0.4˚C cooler to 0.2˚C warmer than the outside temperature. Average temperature inside barns ranged from 23.6 to 25.1˚C, which is indicative the cows were experiencing some degree of heat stress. To help mitigate this problem during the summer, the use of mixing and cooling fans in conjunction with soakers in both pens and the holding area is common among operations in the Midwest.

Mechanically Ventilated Freestalls. Another option for housing dairy cattle in the Midwest comes in the form of mechanically ventilated freestall systems. These systems are classified into three types: negative pressure, positive pressure, and neutral pressure. In the case of a negative pressure system, exhaust fans are used to blow air out of the barn, creating negative pressure in the structure. The opposite is true for positive pressure systems, as fans are used to blow fresh air into the barn, creating a positive pressure environment. Neutral pressure systems act by having fans that both blow air in and out of the barn (Holmes et al., 2013).

In the Midwest, mechanically ventilated freestalls tend to fall under the category of negative pressure systems, and can be classified as either tunnel or cross ventilated facilities. In both systems, the goal is to have a ventilation rate of 1,000 cubic feet per minute (cfm)/cow or greater during hot weather (Holmes et al., 2013). The ventilation rate is calculated by multiplying the cross sectional area through which the air must travel (width of barn*height of barn roof) by the average air velocity. Tunnel ventilated barns work by having fans exhaust air from one end of the barn. This in turn draws fresh air into the other end of the barn, which is open (Holmes et al., 2013). Cross-ventilated barns operate under these same principles. The main difference between the two is the orientation of the air inlet and the exhaust fans. In cross ventilated barns, this causes air to move perpendicular across feed alleys and freestalls, whereas air moves parallel to these areas in a tunnel ventilated barn (Holmes et al., 2013). In order to optimize airflow rate in both systems, baffles were developed that decrease the cross sectional area through which the air must flow, by forcing air to the space below the eaves of the barn. In a tunnel ventilated barn, the baffles are placed perpendicular to the feed alleys and freestalls, meaning that room still needs to be left below them to allow for equipment, such as feed trucks or loader scrapers, to operate. This is where the cross ventilated barns have an advantage, as baffles are placed parallel over the freestalls. Because of this the bottom of the baffle can be placed as low as 7 feet above the stall bed with minimal interference with equipment (Holmes et al., 2013).

Bedding

Providing the cow a comfortable resting surface to lie down is a priority for many dairy producers. In the Midwest, there are a number of options available to producers in terms of both stall type and bedding surface. Much of the recent research in this topic has explored two types of stalls and their effect on cow welfare: deep bedded stalls that utilize sand or recycled manure solids, and mattress based stalls (Cook et al., 2004; Espejo et al., 2006; Husfeldt and Endres, 2012). While a more in depth discussion regarding lameness and cow comfort indicators related to bedding surface will be presented later in this chapter, work has been done to characterize cow preferences for lying surfaces. When able to choose between concrete and a softer resting surface, such as mattresses or straw, cows prefer the softer resting surfaces (Herlin, 1997; Manninen et al., 2002; Norring et al., 2010). When sand is introduced as a bedding option, there has been found to be no preference when compared to concrete (Manninen et al., 2002; Norring et al., 2010). However, after some adaptation period, sand is in fact preferred over concrete and even mattresses (Tucker et al., 2003; Wagner-Storch, 2003).

While work has shown that sand is a preferential bedding surface for cows, producers in the Midwest have not fully adopted it due to costs associated with manure handling equipment, labor, and extra wear and tear on equipment. For this reason, one possible substitute for sand has been the use of recycled manure solids. (Husfeldt and Endres, 2012) But like all bedding options, there are also benefits and costs associated with this source. Godden et al. (2008) found that digested manure solids promoted the greatest amount of bacterial growth when compared with reclaimed sand, wood shavings, and clean sand. Because of these high bacterial counts, some producers are also skeptical of using recycled manure solids due to the perception of an increased mastitis risk. Therefore, all types of bedding surfaces discussed above remain viable options for producers, depending on personal preference and managerial goals.

COW WELFARE, HEALTH, AND PRODUCTIVITY

The concept of animal welfare is not easily defined. Traditionally, producers have always been concerned about providing the best care possible for their animals to ensure that they are healthy and productive. In light of this, the concept of good welfare on a dairy farm is commonly measured as the absence of illness or injury (von Keyserlingk et al., 2009). Increasing public awareness of on farm animal welfare issues has driven some retailers to develop animal welfare standards and evaluations at the supplier level to help ensure consumers that animal products were raised in a humane manner (Mench, 2008). Following these consumer trends, there has also been a recent spike in research related to animal welfare. In the dairy industry specifically, much of this research has been focused on the effect that different production and housing systems have on the physical welfare (lameness, injury, body condition) of a cow and her overall health.

Lameness

Lameness is a topic of major concern pertaining to animal welfare and economic losses in the dairy industry. Along with production losses, lameness is also associated with pain and distress in those animals affected, making it one of the most important welfare indicators in dairy cattle (Whay et al., 1998, 2003). Commonly, lameness is identified on farms by using a scoring system that evaluates the gait and posture of cows (Sprecher et al., 1997). Many times, however, the perception of the level of lameness on a farm is not necessarily accurate, as it is often underestimated by producers or herd managers (Wells et al., 1993; Espejo et al., 2006; Leach et al., 2010; Fabian et al., 2014). When cows are passed over or "missed" for treating a lameness problem, those cows are then subject to changes in normal daily behavior. Lame cows spend more time lying down with longer lying bouts (Walker et al., 2008; Chapinal et al., 2009; Ito et al., 2010), and less time feeding (Gonzalez et al., 2008; Norring et al., 2014) than non-lame cows.

Numerous studies in recent years have worked to investigate lameness in dairy cattle from the standpoint of risk factors in modern freestall systems. In the Midwest, these systems are largely confinement operations that utilize concrete flooring throughout the barns. Somers et al. (2003) found that exposing cows to concrete flooring can potentially lead to a higher proportion of cows with claw disorders when compared with other systems. Along with that, factors including lying surface and stall type (Cook, 2003; Espejo and Endres, 2007; Dippel et al., 2009; Ito et al., 2010; Husfeldt and Endres, 2012), hoof care practices and frequency (Amory et al., 2006; Espejo and Endres, 2007), and the amount of time cows spend away from the pen during milking (Espejo and Endres, 2007) have also been shown to be herd-level risk factors for lameness.

Lameness prevalence on farms continues to be at the forefront of issues pertaining to animal welfare. Numerous on-farm surveys of freestall based systems have reported the average prevalence of lameness to be between 25 and 30 percent (Cook, 2003; Espejo et al., 2006; Ito et al., 2010). von Keyserlingk et al. (2012) investigated lameness in freestalls in British Columbia, California, and the Northeast US. While lameness prevalence in British Columbia and California were found to coincide with percentages found in previous studies, lameness prevalence in the Northeast was 54.8%. Espejo et al. (2006) reported a range of 3.3 to 57.3% in the high-production groups of 53 farms in Minnesota. A large amount of that variation may be attributed to cow housing, and especially bedding surface. Cows housed in deep-bedded sand freestalls were found to have a reduced prevalence of lameness when compared to cows housed in freestalls with mattresses (Cook et al., 2004; Espejo et al., 2006). Additionally, Husfeldt and Endres (2012) found the prevalence of lameness in freestall herds using deep-bedded recycled manure solids to be less than in mattress based freestall operations using solids, and the prevalence of lameness with deep-bedded recycled manure solids was similar to what was found with sand-bedded stalls in previous studies.

Economic Implications. Lameness represents one of the most important diseases causing economic losses on a dairy farm (Enting et al., 1997). The main reasons for these losses result from decreased milk production, reproductive problems and reduced fertility, and an increased risk for premature culling or death. Work done on two dairies in New York found there to be a milk production decrease of 0.8-1.5 kg/day in cows two weeks after a lameness diagnosis, and this persisted further into lactation (Warnick et al., 2001). Green et al. (2002) reported that milk yield was reduced up to four months before a case of lameness was diagnosed and treated, and reduction in 305-day milk yield was estimated at 360 kg. It was also reported that cows that had been severely lame 4, 6, and

8 months previously gave 0.51 kg/day, 0.66kg/day, and 1.55kg/day less milk, respectively, and from that, it was estimated that a case of severe lameness in the first month of lactation would result in a 350 kg reduction in 305-day milk yield (Archer et al., 2010).

Financial losses due to decreased reproductive performance and fertility can also be greatly attributed to lameness problems. After calving, cows classified as lame had 3.5 times greater odds of delayed ovarian cyclicity than their nonlame counterparts (Garbarino et al., 2004). Cows that became lame within the first 30 days postpartum had lower conception rates at first service (17.5% vs 42.6%) and a higher incidence of ovarian cysts (25.0% vs 11.1%) (Melendez et al., 2003). Lower conception rates result in a longer number of days open. Hernandez et al. (2005) reported the median time to conception for lame cows was 36 to 50 days longer than for nonlame cows. Lame cows were at a 15% lower risk of pregnancy than nonlame cows, and this number grew to a 24% lower risk for severely lame cows (locomotion score ≥ 4) (Bicalho et al., 2007). Bicalho (2007) also reported an increase in the hazard ratio of cows being culled or dying: 1.45 for lame cows (locomotion score ≥ 3) compared to nonlame cows (locomotion score <3), and 1.74 for severely lame cows (locomotion score ≥ 4) in comparison to cows that were not severely lame (locomotion score <4). Cramer et al. (2009) reported similar findings, as hazard ratios for culling for cows with noninfectious foot lesions ranged from 1.26-1.72. In another study, cows that were diagnosed as lame in the first 60 days after calving had 2 times greater risk of being culled during the period from 121 to 240 days after calving than nonlame cows (Booth et al., 2004). Overall, lameness continues to be a major focus of animal welfare on farms and it has been shown to have significant negative effects on profitability.

Hock Lesions

Along with lameness, another physical indicator that can be used to evaluate animal welfare on a farm is the presence or absence of hock lesions. Lesions are created by rubbing or friction of the joint on a hard surface, such as exposed freestall bases, certain bedding types, or rails. They are first characterized by hair loss on the hock. However, if trauma to the joint persists, fluid may begin to collect on the hock making it appear swollen, and also increasing the risk for ulceration or infection.

Much of the work that has been done on this topic has been focused on identifying not only prevalence rates of lesions in modern freestall operations, but recognizing how varying housing features may contribute to lesions and what would be developing risk factors. Weary and Taszkun (2000) found that 73% of cows had hock lesions in a study that involved 1752 lactating cows on 20 freestall farms in British Columbia. Work done by von Keyserlingk et al. (2012) found prevalence rates of hock injuries in freestalls in British Columbia, California, and the Northeast United States to be 42%, 56%, and 81%, respectively. In characterizing housing features and their attribution to hock lesions, both prevalence and severity of lesions has been found to be greater in herds housed on mattress based freestalls when compared to herds using deep bedded sand (Weary and Taszkun, 2000; Fulwider et al., 2007; Barrientos et al., 2013; Zaffino Heyerhoff et al., 2014). However, even with extensive research proving the advantage of sand bedding in relation to mattresses in helping to mitigate hock lesions, producers are still reluctant to use sand. This is likely due to the extra costs of labor, handling facilities, and equipment required to utilize sand successfully. With that said, Husfeldt and Endres (2012) found that cows housed on deep bedded recycled manure solids did show improved hock scores in relation to mattress based herds, leaving reason to believe there are other possible options for helping to improve this aspect of animal welfare in the future.

Culling and Mortality

By definition, culling is the departure of cows from a herd due to sale, slaughter, salvage, or death, and describes the percentage of cows removed from a herd (Fetrow et al., 2006). Reasons for removal have been found to vary widely (Smith et al., 2000), but are commonly classified as either voluntary or involuntary removals. Voluntary culls are those cows that are sold for dairy purposes or are otherwise found to be normal except for poor milk production, whereas involuntary culls are those cows that are culled due to disease, mastitis, severe lameness, poor reproduction, death, or any other categories of the like (Fetrow et al., 2006). Culling decisions are an economic comparison of the current cow to her potential replacement (Hadley et al., 2006), and therefore should be a dynamic decision based on individual farm goals while also considering future implications of the culling decision (Fetrow et al., 2006; Hadley et al., 2006).

From an animal welfare perspective, involuntary culling and mortality have become topics of great interest as they both can be used as numerical indicators of cow health and well-being at the farm level (de Vries et al., 2011). Mortality rates, in particular, appear to be a growing problem across the industry. Work done by the

USDA:APHIS:VS National Animal Health Monitoring System (NAHMS) showed an increase in annual mortality rates from 4.8% in their 2002 survey to 5.7% in their 2007 survey (USDA, 2002; USDA, 2007a). Work done by Husfeldt and Endres (2012) reported a mortality rate of 8.2- 8.6% in Upper Midwest herds using recycled manure solids as a bedding source, and in a recent study of 6 million DHIA records from 10 Midwest states, mortality rates in larger herds (>500 cows) were 7.1% (M. Shahid, University of Minnesota, unpublished data).

While those rates may seem alarming, one area of particular concern is the stage of lactation in which a majority of deaths are occurring. Hadley et al. (2006) reported that 42% of deaths occurred during the first 60 days in milk (**DIM**). Similar results were found by Dechow and Goodling (2008), who reported also finding 42% of mortalities occurring from day 0 to day 60 of lactation, but increased to 52% when coupled with the 21-day period before an individual cows' expected calving date. This leaves reason to believe that the transition period is a crucial time in the lactation cycle for a cow in terms of survival. This period is usually defined as the period from 3 weeks before to 3 weeks after calving. It is a time when she is not only under a great deal of stress from calving, but operating in a negative energy balance makes the cow more susceptible to a multitude of metabolic diseases and other problems. With cow health such a large part of overall welfare on a farm, the transition period will continue to be a critical area in that regard.

Morbidity

In recent years, there have been great advancements in dairy health resulting from a shift to disease prevention, rather than treatment (LeBlanc et al., 2006). Along with that, research has led to the ability to identify the interconnected risk factors associated with specific diseases, and allowed for the redefining of diseases to include even subclinical conditions (LeBlanc et al., 2006). However, common on-farm record keeping systems rely largely on user-defined inputs disease and treatment records. Work done by Wenz and Giebel (2012) found that user-defined health records lacked accuracy and consistency needed for efficient evaluation at the farm level to help in making well-informed health management decisions, leaving room for future work in standardizing on-farm health records.

Transition Period. Disease prevention, identification, and treatment is an extremely important task in the day to day operation of a dairy farm. Perhaps the most import time during a cow's life in respect to health is during the transition period. This period is characterized by natural changes in energy balance, as a cow's energy demand for milk production is not met solely by energy consumed from feed (Bauman and Currie, 1980; Herdt, 2000). Cows that are not able to meet these changes in energy metabolism are then at a higher risk for metabolic diseases and decreased productivity (Drackley, 1999).

Common metabolic problems encountered on dairies include ketosis, displaced abomasum (DA), retained placenta, metritis, and milk fever. Leblanc (2010) estimated that up to one-third of cows may be affected by some form of metabolic disease or infection during the early part of lactation. A metabolic problem that has demanded much attention recently is ketosis, and specifically subclinical ketosis. This condition arises due to a negative energy balance from decreased dry matter intake, and is indicated by an increase in nonesterified fatty acid (NEFA) and beta-hydroxybutyrate (BHBA) in the circulating blood serum and a decrease in blood glucose concentrations (Drackley, 1999). Subclinical ketosis is characterized by serum BHBA levels greater than 1.4 mmol/L with the absence of clinical symptoms of ketosis (Duffield et al., 1998; Iwersen et al., 2009). The incidence rate of subclinical ketosis in herds has been reported at over 40% during the first weeks of lactation (McArt et al., 2012). Cows with subclinical ketosis in the first or second week after calving have also been found to be at increased risk for DA, metritis, clinical ketosis, increased severity of mastitis, and lower milk production (Leblanc, 2010).

Mastitis. Along with the aforementioned problems, mastitis also remains a prominent health concern for producers as it continues to be the most common health problem in the dairy industry (USDA, 2007a). From an economic standpoint, it is also one of the most costly issue affecting dairy cattle (Kossaibati and Esslemont, 1997; Bradley, 2002). By definition, mastitis is an inflammation of the mammary gland. It is commonly classified as either contagious or environmental mastitis, and while most often caused by bacteria, it has also been linked to mycoplasma, yeasts, and algae (Bradley, 2002). Contagious mastitis pathogens are spread from host to host, and are adapted to live within the teat canal or mammary gland. They are often associated with chronic infections resulting in a higher somatic cell count (Fenlon et al., 1995; Barkema et al., 1998). Common pathogens of contagious mastitis are *Staphylococcus aureus*, *Streptococcus agalactiae,* and *Mycoplasma* (Fox et al., 2005; Nickerson, 2011). Environmental pathogens, on the other hand, typically invade the mammary gland and multiply quickly. This triggers an immune response by the host cow and the pathogen is then rapidly eliminated (Bradley, 2002). Common environmental pathogens include forms of streptococci and coliforms. Among the streptococci are *Streptococcus uberis* and *Streptococcus dysgalactiae,* whereas *Escherichia, Klebsiella, and Enterobacter* are the most common of the coliforms (Oliver et al., 2011).

A number of studies have worked to calculate clinical mastitis incidence on farms. Peeler et al. (2000) found an incidence rate of 22.8 cases per 100 cow-years in a survey of over 1,800 British dairy farms with a bulk tank somatic cell count of less than 100,000 cells/mL. Likewise, on a study of 106 farms in Canada, the average incidence rate of clinical mastitis was found to be 23.0 cases per 100 cow-years with a range from 0.7 to 97.4 per herd (Olde Riekerink et al., 2008). Husfeldt and Endres (2012) found incidence rates to range from 9.3 to 108.7 with an average of 66.3 cases per 100 cow-years for cows housed on deep bedded recycled manure solids, and a range from 13.2 to 107.6 with an average of 49.0 cases per 100 cow-years in herds using mattresses.

Reproduction

Reproduction on a dairy farm is an important measure of overall productivity and profitability (Louca and Legates, 1968; Britt, 1985; De Vries, 2006). Many of the topics pertaining to facility design and animal health and welfare that were discussed earlier have significant effects on reproductive performance, and research describing their effects on dairy cattle reproduction is well documented. Environmental stress related to facility management (Collier et al., 1982; Jordan, 2003; Rensis and Scaramuzzi, 2003), lameness (Barkema et al., 1994; Melendez et al., 2003; Bicalho et al., 2007), and cow health (Fourichon et al., 2000; Grohn and Rajala-Schultz, 2000) have all been found to have profound effects on the reproductive performance of dairy cattle. Thus, proper management in these areas is critical for reproductive success.

The goal of any reproductive program is to maximize pregnancy rate. This is commonly defined as the proportion of cows that become pregnant that are eligible to become pregnant during each estrous cycle and is the product of heat detection and conception rates. Pregnancy can be achieved through either natural service or artificial insemination. Aside from obvious genetic benefits, research has also shown economic benefits with the use of artificial insemination (Lima et al., 2010). Industry wide, artificial insemination accounts for 78.3% of cow breedings and 66.8% of heifer breedings (USDA, 2007b). However, a survey of reproductive practices on large commercial farms in the United States found that all of the farms utilized artificial insemination to some extent in their breeding protocol (Caraviello et al., 2006). With artificial insemination, a number of options are available to producers for breeding purposes, including observing and breeding to natural estrus, synchronizing estrus through the use of a natural hormone protocol, or some combination of the two methods. Management factors, such as labor availability and personal preference, should be taken into consideration when selecting a breeding program with the end goal of achieving successful reproductive performance.

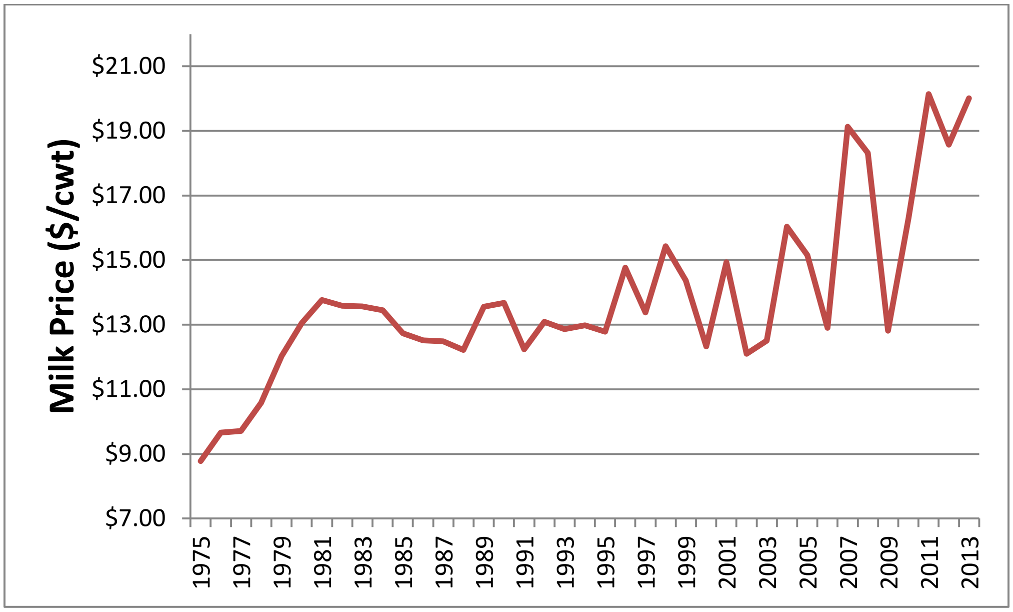
SOCIAL AND ECONOMIC SUSTAINABILITY

As the trend for fewer farms with more cows per farm has progressed, and the number of people with ties to agriculture continues to decrease with urbanization, continuous improvement within the three pillars of sustainability (environmental, social, and economic) will be critical for the viability of the industry in the future (von Keyserlingk, 2013). To achieve true sustainability in the long-run, the dairy industry must adopt practices that coincide with social and environmental concerns, but are also profitable. Two key topics related to the focus of this paper fall under the categories of social and economic sustainability.

Social Sustainability. Social sustainability directly involves the concepts and issues pertaining to animal welfare that was discussed earlier in this chapter. Labor also falls under this category. Labor management, in particular, will be a key issue under the social sustainability blanket as more research is focused on worker rights, safety, and welfare on large scale operations. The final aspect of social sustainability is community impact. Obviously, as consumers of dairy products, people will want to ensure that dairies are producing a safe and healthy product. Likewise, as dairies continue to increase in size, questions are raised as to the quality of life of the people living near them. Schmalzried and Fallon Jr. (2007) assessed the opinions of people living close to large-scale dairy operations and compared them to individuals in control groups living at least 8 km away. They found no differences between the groups, concluding that these large-scale operations, when properly managed, are not necessarily a detriment to quality of life. They did, however, suggest that new operations should be built in areas with few neighbors, and where no future residential development is expected to take place.

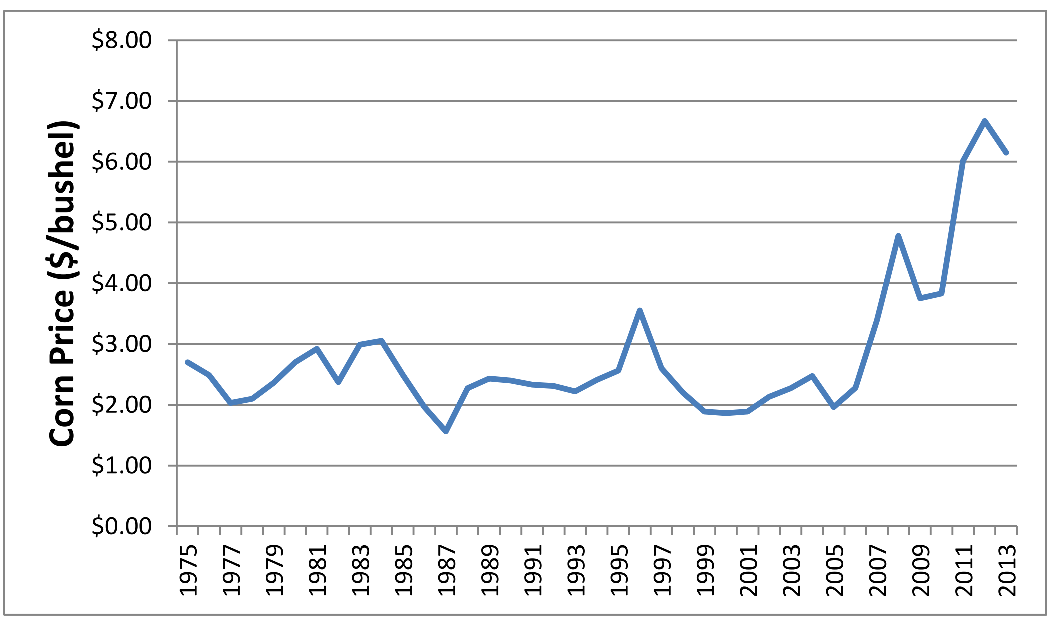
Economic Sustainability. Economic sustainability as it relates to the dairy industry is reliant on profitability. In recent years, this has been an industry spotlight because of the extreme market volatility. The volatility comes in the form of commodity markets that both affect income generated from milk sales as well as the cost of feed (Dhuyvetter, 2011). Figures 1-4 and 1-5 display yearly average historical prices for milk and corn in the United States, and demonstrate the volatility that has been experienced recently in these markets.

Figure 1-4 U.S. Average Yearly Price, Milk (1975-2013)



Source: USDA, National Agriculture Statistics Service

Figure 1-5 U.S. Average Yearly Price, Corn (1975-2013)



Source: USDA, National Agriculture Statistics Service

One tool commonly used by producers to monitor profitability is the use of cost of production accounting. This allows producers to precisely track all costs related to the physical farm structure and operation, and know, relative to the amount of milk production, how much it is costing to produce 100 pounds of milk. This can then be compared to the gross value of production, which is the price received for milk produced, and reveals either positive or negative net returns. Work done by MacDonald et al. (2007) revealed cost of production advantages and increases in net returns as herd size increased. Table 1-1 shows a table of cost of production by herd size, organized from 2005 ERS estimates.

Table 1-1

Dairy costs of production, by herd size, 2005

	Enterprise size (number of milk cows)					
	<50	50-99	100-199	200-499	500-999	>999
Mean herd size	35	69	133	295	666	2083
Output per cow (lbs)	15,055	17,149	18,228	19,487	20,719	20,195
	Dollars per hundredweight					
Total operating costs	12.30	12.94	11.51	11.31	11.07	9.74
Purchased feed	3.60	3.75	4.12	5.00	5.64	5.99
Homegrown feed	5.02	5.07	4.06	3.01	2.58	1.47
Grazed feed	0.41	0.15	0.11	0.10	0.02	0.01
Allocated overhead	17.79	12.56	9.31	6.61	5.00	3.85
Hired labor	0.50	0.80	1.34	1.84	1.80	1.61
Unpaid labor	10.60	6.10	3.13	1.34	0.54	0.17
Capital recovery	5.26	4.56	3.89	2.55	2.03	1.66
Total costs	30.09	25.50	20.82	17.92	16.07	13.59
Gross value of prod.	17.87	17.56	17.20	17.25	16.56	16.54
Net returns	-12.22	-7.94	-3.62	-0.67	0.49	2.95

Source: MacDonald et al., 2007

The results indicate that larger farms (more than 999 cows) have a significant advantage in terms of operating costs over all other size classes. Allocated overhead is also decreased as farm size increases, as the incremental value of adding additional labor or capital appears to be outweighed by the additional production from adding more cows. This concept is extremely important as we analyze recent trends in the industry, as it would appear advantages in cost of production are a significant drive force in the consolidation of dairy operations. It has already been established that profitability is a key component to economic sustainability, and larger operations appear to be more adept in handling some of the market volatility that the industry has experienced in recent years with their shown cost advantages.

CONSUMER TRENDS

Coinciding with the changes observed in industry structure, the consumer market of the United States dairy industry has also continued to evolve. Over the past 35 years, fluid milk and cream consumption in the United States has decreased by just over 25%, from 261 pounds per capita in 1975 to 195 pounds per capita in 2012, based on fluid weight (USDA ERS, 2013). While this number may seem alarming, the decrease has actually been offset somewhat from increased demand for products such as sour cream and yogurt. Yogurt production, specifically, has seen dramatic increases in production over this same time period, from 425 million pounds in 1975 to 4.4 billion in 2012 (USDA ERS, 2013b). Even with the decrease in fluid milk consumption, per capita consumption of dairy products in the United States has actually increased, due in large part to cheese. In 1975, U.S. per capita cheese consumption was 14.5 pounds. By 2012, that number had more than doubled to 33.5 pounds (USDA ERS, 2013a).

The increase in consumer demand for cheese may bring about significant changes in how milk it utilized. With the change in the type of dairy products that are consumed, questions are then raised as to the most efficient way to produce them. Capper and Cady (2012) compared the overall environmental impact of Jersey milk compared with Holstein milk for cheese production. They found that less Jersey milk was required relative to Holstein milk to produce the same amount of cheese, a result of higher fat and protein content commonly found in milk from Jerseys. They also found that, even though daily milk yield from Jersey cows was less and more cows were required to meet the demand for the required cheese yield, their total carbon footprint was actually less than that of Holstein cows. This resulted from less feed, and therefore less cropland required, due to a lower body weight, as well as decreased water use. Although the U.S. dairy herd only comprises 5.3% Jersey cattle in relation to the Holstein that make up 90.1% of the population (USDA, 2007a), this research hints at one area of change that could occur to improve efficiency within the industry.

CONCLUSIONS

The aim of this chapter was to provide a background related to the current and historical structure of the dairy industry, along with describing modern dairy facilities and their management. Topics including cow welfare, health, and productivity were covered, as they play a vital role in social sustainability. Likewise, a brief discussion of the current economic structure of the industry was also presented to help better understand some of the major driving forces behind structural change. Specifically related to the discussion of cow health, welfare, and productivity, the physical welfare factors of lameness and hock lesions were discussed as to their negative effects on cow productivity. Health factors such as mastitis, and mortality and culling were also discussed thoroughly as measurements of overall well-being as well as productivity in current operations. Because of this, these factors will be looked at more in depth in the coming chapters focused on a case study of large dairy operations (> 2,500 cows) in the Upper Midwest, with a specific focus on prevalence, risk factors, and possible effects on profitability.

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CHAPTER 2:

Management and animal welfare characteristics of large dairy operations in the Upper Midwest

OVERVIEW

Recent trends in dairy farm structure in the United States have included a decreasing number of operations while farm size has increased, especially the share of milk production from very large farms (> 2,500 cows). The objective of this cross-sectional study was to describe common management practices and to characterize some aspects of animal welfare on farms with more than 2,500 cows in the Upper Midwest. The study included 15 commercial dairy operations in Minnesota, Wisconsin, Iowa, and South Dakota. All operations had over 2,500 lactating cows in a freestall system, and average herd size was 4,972 cows. Twelve of the farms had Holstein cows, 2 farms had Jersey, and 1 farm had Jersey x Holstein crosses. Farms were visited twice in July or August of 2012 and 2013. At the time of each visit, at least 1 high producing pen of mature cows and 1 pen of fresh cows were assessed for locomotion. Likewise, at least 1 pen of high producing mature cows was scored for hygiene and hock lesions. On farm-herd records were collected for a 2-yr period and used to investigate mortality, culling, and mastitis incidence. Overall lameness prevalence and severe lameness were 16.7% and 5.1%, respectively. The presence of an on-farm hoof trimmer and increased trimming frequency were associated with lower lameness prevalence in these very large operations. Overall hock lesion prevalence was 22.8% and severe hock lesion prevalence was 2.3%. We found lower prevalence of hock and severe hock lesions in Jersey herds. In

addition herds that utilized sand bedding had lower overall hock lesion prevalence. Mortality rate across all herds was 7.4%. Jersey herds had lower mortality rates when compared with Holstein and Crossbred counterparts. Overall clinical mastitis incidence was 62.5 cases per 100 cow-years. Jersey herds had lower clinical mastitis incidence, and there was also an association between sand bedding and lower mastitis incidence when compared to farms utilizing RMS as a bedding source. Before characterizing management practices that optimize welfare on these large operations, additional research is needed with a larger number of herds and including additional explanatory risk factor variables.

INTRODUCTION

The structure of the dairy industry has experienced tremendous change in recent decades. Some of the main driving forces behind this change include technological innovation, changes in the milk production system, and specialization (Blayney, 2002). These factors, combined with producers taking advantage of economies of scale to cope with the financial stress that has been realized by the industry, have driven dairy farming to consolidate (MacDonald et al, 2007a). This has resulted in a decrease in the overall number of farms, while average herd size has increased.

Larger farms initially began appearing in Western States during in the 1970s (MacDonald et al., 2007b). These farms operated in a fundamentally different way than the pasture-based systems of the traditional dairy states in the Northeast and Upper Midwest. Cows were housed in large barns or drylot pens, and many operations relied on hired labor and purchased feed, instead of family labor to take care of the cows and grow feed (MacDonald et al., 2007b). In 1975, California and Texas were the only Western States in the top 10 states for milk production, accounting for roughly 12.2% of the total production in the U.S. (USDA, 1976). By 2013, this list grew to include 3 other Western States: Idaho, New Mexico, and Washington. The total share of U.S. milk production from those 5 states grew to 39.1% with an average herd size of 1,204 cows.

Aside from the growth in the number of large operations in Western States, the Upper Midwest has also shown recent growth in the share of milk production coming from larger farms. From 2000 to 2012, the percent of state milk production coming from farms with more than 500 head increased nearly threefold in Minnesota, Iowa, South Dakota, and Wisconsin; from 8.5 to 32.6% in Minnesota, 5.0 to 44.1% in Iowa, 26.0 to 75.2% in South Dakota, and 9.0 to 38.1% in Wisconsin (USDA, 2001; USDA, 2014). Very large operations (>2,500 cows) have also begun to make an impact on milk production in the Upper Midwest. In 2012, these operations accounted for just 0.2% of the total number of operations in these states, but were responsible for over 11% of total milk production that occurred in the four-state region (USDA, 2014).

While structural changes in the dairy industry have been occurring over the past decades, one topic of growing interest is public perception and education in the area of animal welfare. There is well documented research in the area of dairy cattle welfare across various housing systems (Cook et al., 2003; von Keyserlingk et al., 2012; Husfeldt and Endres, 2012). One of the greatest welfare concerns in the dairy industry is lameness (Whay et al., 2003). Lameness not only has economic implications (Enting et al., 1997), but it is also associated with pain and distress in affected animals (Whay et al., 1998), and therefore should be of great concern in relation to public perception. Culling and mortality have also become strong welfare indicators as both can be used as numerical indicators of cow health and well-being (de Vries et al., 2011). Increased mortality rates and culling, especially in the early stages of lactation, may indicate compromised animal health and welfare (Thomsen et al., 2004). Larger herd size has been identified as a risk factor for mortality (Alvåsen et al., 2012). With the trend for increasing farm size, it is important to understand how animal welfare is impacted by this structural change.

It has been well established that the structure of the dairy industry has been altered significantly over past years. Cost advantages of larger farms appear to be driving the consolidation within the dairy industry. This trend appears to be taking hold in the Upper Midwest, and more specifically, a significant amount of milk seems to be supplied by farms with more than 2,500 cows, even though this class of farm size only makes up a small percentage of the total number of dairy operations. To our knowledge, little, if any, information exists regarding the operation of these farms in the Upper Midwest. Therefore the objective of this study was to describe common management practices and to characterize some aspects of animal welfare, including risk factors for lameness, hock lesions, mortality, and mastitis on farms with more than 2,500 cows in the Upper Midwest.

MATERIALS AND METHODS

This cross-sectional observational study was conducted between July 2012 and August 2013 on 15 large dairy operations in the Upper Midwest. Herds were selected on the basis that they had more than 2,500 lactating cows, utilized freestall housing, and had been in operation or under current management for a period of at least 1 year prior to our first visit. No other constraints were included in an effort to maximize sample size. Operations were identified through extension educators, industry personnel, and other producers. Following the identification process, producers were contacted to confirm the selection criteria and to obtain consent to participate in the study.

Data Collection

Each operation in the study was visited twice during the study period to perform on-farm data collection. The first visit was conducted between July and October of 2012, with a follow up visit between July and August of 2013. Data collection consisted of visually scoring at least 1 high producing pen of mature cows for locomotion, hygiene, and hock lesions. The fresh cow group was also scored for locomotion on each farm. Records were obtained from the on-farm herd management software during each visit to allow for a 2-yr analysis of herd records to be performed. On farm interviews were conducted with herd managers or owners to obtain information regarding farm management practices using a 25 question survey. Daily bulk tank information was obtained for January to December 2012, when accessible, from each herd's processor.

Cow Measurements. Animals in the fresh and high pens on each farm were evaluated for lameness using a 5-point locomotion scoring system with 1=normal locomotion and 5 = severely lame (Flower and Weary, 2006). All scoring was performed by the same observer as cows exited the milking parlor. All cows in at least 1 high producing pen of mature cows (2 or more lactations) and 1 pen of fresh cows (mature cows or mixed lactations) were assessed on each farm. Lameness prevalence for each pen was calculated as the number of cows with locomotion score (**LS**) ≥ 3 divided by the total number of animals that were scored in the pen. Cows with LS ≥ 4 were classified as severely lame, and severe lameness prevalence was calculated by dividing the number of severely lame cows by the total number of animals scored in each pen.

Cows were scored for hock lesions (**HL**) and hygiene in the milking parlor during milking. All assessments were performed by 1 observer, and at least 1 pen of high producing mature cows was scored on each farm. HL were scored on a 3-point scale, where 1 = no lesion (normal), 2 = hair loss (mild lesion), and 3 = hock swelling with or without hair loss, or open lesions (severe lesion). Hock lesion prevalence for each pen was calculated as the number of cows with HL ≥ 2 divided by the total number of cows scored in each pen. Prevalence of severe hock lesions was calculated as HL ≥ 3 divided by the total number of cows scored in the pen. Hygiene was assessed by evaluating the cleanliness of the udder and legs using a 4-point scale where 1 = clean and 4 = dirty (Schreiner and Ruegg, 2002). In total, 22,913 cows were assessed for locomotion and 11,777 cows were assessed for hock lesions and hygiene.

Facility Measurements. Freestalls were measured for stall width, total stall length, body resting length, and neck rail height. Stall width was measured as the width between 2 consecutive stall loops, on center. Total stall length was measured from the center of 2 rows of freestalls facing head-to-head to the edge of the curb in the back of the stall or from the outside wall to the curb. Body resting length was measured as the length from the base of the brisket locator (if one was present) to the edge of the curb at the back of the stall. If no brisket locator was present, this was measured as the distance from the neck rail to the edge of the curb in the back of the stall, parallel to the resting surface. Neck rail height was measured as the distance between the bottom of the neck rail to the stall surface. An average of each stall measurement for each farm was calculated using a sample of randomly selected stalls (>5).

Mastitis Incidence. Mastitis incidence for each herd was calculated as the number of cases of mastitis per 100 cow-years at risk. This analysis was done for two 1-yr periods from July 2011 to July 2013. The number of mastitis cases and the number of cows at risk were obtained from each farm's on farm record system. Number of cows at risk during the year was calculated as the average of the weekly lactating herd size, as reported in the on-farm record system. Reported clinical mastitis cases were considered to be a new case if more than 14d had passed between the previous and current case of clinical mastitis (Barkema et al., 1998).

Culling and Mortality. Information on culling and mortality was also collected from the on-farm record keeping system, and analyzed over the 2-yr period from July 2011 to July 2013. Turnover rate was calculated as the number of animals that left the dairy (sold or died) over the course of each 1-yr period divided by the average weekly herd inventory during that period (Fetrow et al., 2006). The percentage of culling during the first 30 and first 60 DIM was calculated by dividing the number of animals that were sold or died during the first 30-d and 60-d of lactation in a 1-yr period divided by the total number of animals that were sold or died during that same period. Reasons for culling were categorized as low production, lameness or injury, mastitis, reproduction, transition problems, abortion, udder conformation, sick, miscellaneous, or unknown reasons.

Voluntary culls were considered for cows that left the herd due to low production or udder conformation. Involuntary culls consisted of any culling due to lameness or injury, mastitis, reproduction, transition problems, abortions, sick, miscellaneous, and unknown reasons. One herd was excluded from the analysis of culling reasons due to incomplete records.

Mortality rate was calculated as the number of animals that died during a 1-yr period, divided by the average herd size during that period. Mortality during the first 30-d and 60-d of lactation, as a percent of total deaths, were calculated by dividing the number of cows that died during the first 30-d and 60-d of lactation during each 1-yr period by the total number of cows that died during each 1-yr period. Deaths on farm were categorized as injury, mastitis, lameness, sick, down cow, transition diseases, dystocia, euthanasia, miscellaneous, or unknown reasons.

Pregnancy Rate. Pregnancy rate was also monitored on each farm over the 2-yr period utilizing the on-farm record system. Overall pregnancy rate was calculated as the number of cows that became pregnant divided by the number of cows at risk of becoming pregnant in a 21-d period.

Statistical Analysis

The MEANS procedure (SAS Institute Inc. Cary, NC) was use to describe average farm measurements such as herd size, milk production, milk components, somatic cell counts (SCC), pregnancy rate, number of employees, number of rations fed, hoof trimming frequency, bedding frequency per week, and stall dimensions. Average farm welfare measurements were also analyzed in this manner for mortality rate, turnover rate, hygiene scores, and mastitis incidence. The FREQ procedure (SAS Institute Inc. Cary, NC) was used to classify lameness prevalence and hock lesion prevalence, along with various management characteristics such as reproduction management, employee training, and youngstock management.

The MIXED procedure of SAS (SAS Institute Inc. Cary, NC) was used to evaluate risk factors for lameness prevalence, hock lesion prevalence, mortality rates, and mastitis incidence. The UNIVARIATE procedure (SAS Institute Inc. Cary, NC) was used to evaluate normality, and variables that were found to be non-normal were log transformed for analysis and back transformed with the 95% confidence interval used for interpretation. Associations with on-farm variables were evaluated with a univariate model as a screen test. Farm and year were used as random variables in the analysis, and pen nested within farm was included as a random factor for the associations with lameness and hock lesion prevalence. Variables that were identified in the univariate screening test ($P < 0.3$) were used to build a multivariate model using the MIXED procedure (SAS Institute Inc. Cary, NC). In the multivariate model, the backwards stepwise procedure was used until all remaining variables in the multivariate model were significant ($P < 0.05$).

RESULTS AND DISCUSSION

Herd and Management Characteristics

Farms were located in Wisconsin (6), Minnesota (5), Iowa (3), and South Dakota (1). According to the Census of Agriculture (USDA, 2012) there were 46 dairy operations with 2,500 cows or more in those 4 states, therefore, 32.6% of the total number of operations of this size in the 4-state region were included in the study. In terms of breed composition, 12 of the operations had Holstein, 2 had Jersey, and 1 had predominantly Holstein and Jersey crosses. Seven of the operations housed cows in freestalls with deep bedded sand, 7 operations utilized deep bedded recycled manure solids (**RMS**), and 1 farm utilized RMS in a 2-3 inch layer on top of mattress based freestalls. Of the Jersey farms, 1 operation utilized sand bedding while the other utilized deep bedded RMS. Within farms that utilized sand, 3 utilized a mechanically separation system while the remaining 4 farms utilized sand settling lanes. Methane digesters were operated by 6 of the 8 farms that housed cows on RMS and 2 of the farms that housed cows on sand. Eight of the farms housed the majority of cows in mechanically ventilated (i.e. cross ventilated or tunnel ventilated) freestall barns, whereas 7 farms housed cows in naturally ventilated freestall barns. However, barn type was not found to be associated with any of the variables that were evaluated in this study.

Average herd size (mean ± SD) across all farms was 4,972 ± 2,652 cows with a range from 2,606 to 13,266. Annual bulk tank records were obtained from 12 of the participating farms. Daily energy-corrected milk (ECM) production per cow based on milk sold was 31.9 ± 3.3 kg. Milk fat content was 3.85 ± 0.32% and milk protein content was 3.15 ± 0.17. Bulk tank somatic cell count (BTSCC) was 190,250 ± 37,860 cells/ml. Hygiene scores averaged 2.5 ± 0.3 and ranged from 2.0 to 2.9. Stall length was 235.4 ± 10.8 cm, stall width was 119.7 ± 2.8 cm, body resting length was 178.7 ± 10.0 cm, and neck rail height measured 110.8 ± 8.0 cm. Average 21-d pregnancy rate was 21.7 ± 4.6%.

The number of employees was 48.5 ± 31.2, with a range from 27 to 155. From this, milk sold per employee was 1,120,745 ± 180,472 kg, and the number of cows per employee was 105.1 ± 21.6. All 15 farms in the present study utilized employee training and retraining protocols, and every farm also offered some form of 3rd party training to their employees. For reproduction, all 15 farms utilized artificial insemination (AI) as the sole form of breeding and 100% of the farms utilized hormonal synchronization or timed AI programs in their reproductive protocols. This coincides with work done by Caraviello et al. (2006) that found 87% of herds utilized this practice in a survey of large commercial farm across the US. In regards to hoof trimming, the average number of trims during a cow's lactation was 1.8 ± 0.7 times, and ranged from 1 to 3 times. Ten farms (66.7%) employed an in-house hoof trimmer, whereas 5 (33.3%) hired an outside service.

The number of rations fed on farm was 5.9 ± 2.0, and ranged from 2 to 10. The large range in number of rations is likely due to producer preference. Separate rations allow producers to target specific groups of cows at various lactation stages; however, more intense feeding management is needed to ensure each ration is formulated and mixed accurately. Sova et al. (2014) found variability in daily ration composition and variation in the rations that were fed versus the formulated rations in a study of 22 commercial freestall operations. Those authors found that less variability in the energy content of the ration was associated with greater dry matter intake, milk yield, and milk production efficiency, and lower variability in the percent of long particles in the ration was associated with greater milk yield and milk production efficiency. Bedding frequency per week was 3.1 ± 1.8 times. For the 7 farms that utilized sand as bedding, bedding frequency ranged from 1 to 3 times per week, whereas farms that utilized RMS ranged from 3 to 7 times per week. Husfeldt et al. (2012) found that on 38 operations utilizing RMS, 60% of the farms added RMS to stalls 3 or more times per week, while the majority of the remaining farms added fresh bedding twice per week.

Lameness

Lameness prevalence across all farms in this study was 16.7% and severe lameness prevalence was 5.1%. This overall lameness prevalence is lower than the lameness prevalence of 25 to 30% reported in a number of on-farm surveys of freestall based systems (Cook, 2003; Espejo et al., 2006; Ito et al., 2010). Discrepancies in these values likely result from the fact that those studies included a wide variety of stall surfaces in their evaluation. Fourteen of the 15 farms in the current study utilized deep beds with either sand or RMS. Research has shown a preference for softer resting surfaces and deep beds (Tucker et al., 2003), and softer resting surfaces have been found to lead to longer lying times and less time standing (Tucker and Weary, 2004). Research has also found that lying comfort is a risk factor that influences lameness prevalence in dairy herds (Dippel et al., 2009).

Table 1 shows the results of the univariate analysis of variables and their association with lameness prevalence and Table 2 displays the results of the univariate analysis for severe lameness prevalence. All farms in the analysis utilized sand or RMS in deep-bedded freestalls. One farm that solely utilized mattresses with a layer of RMS on top of the mattresses was excluded from the analysis, because there has been much research done showing that mattress based freestalls are a risk factor for higher lameness prevalence when compared to deep bedded sand (Cook et al., 2004) and deep bedded RMS (Husfeldt and Endres, 2012). Bedding type, breed, DIM, the presence of an on-farm hoof trimmer, hoof trimming frequency, and the interaction of trimming frequency and bedding type were found to have significant associations with both lameness and severe lameness prevalence and were included in the initial multivariate model.

Results of the final model for lameness is found in Table 1 and results for severe lameness prevalence are reported in Table 2. The presence of a trained on-farm hoof trimmer ($P = 0.02$) and hoof trimming frequency ($P < 0.001$) were found to be associated with lameness on these large dairy operations, and hoof trimming frequency was also found to be associated with severe lameness ($P = 0.002$). Farms with a trained on-farm hoof trimmer had lower lameness prevalence (11.3%) than those farms that hired an outside hoof trimmer (16.0%). We suggest that the lower prevalence of lameness on farms with an on-site hoof trimmer could be due in part to the fact that clinically lame cows are able to be treated right away when they are noticed. The economic consequences of lameness have been well studied, namely financial losses due to decreased milk production (Warnick et al., 2001; Green et al., 2002; Archer et al., 2010), reduced fertility (Garbarino et al., 2004; Hernandez et al., 2005), and premature culling or death (Bicalho et al., 2007; Cramer et al., 2009). As the results of this study indicated, lameness was lowered with the presence of an on farm hoof trimmer. The gains made from decreased financial losses due to lameness may make it beneficial to have an on-site hoof trimmer in these large systems.

Espejo and Endres (2007) identified hoof trimming frequency as a risk factor for lameness in high producing Holstein cows in Minnesota housed in a freestall system. They found that lameness prevalence was greater when hooves were only trimmed when needed, compared to trimming once or twice during lactation and when needed. In the current study, hoof trimming was done once, twice, or three times during a lactation, and when cows needed it. Herds that trimmed 3 times during lactation had lameness prevalence of 6.9% and severe lameness prevalence of 1.5%, and were found to have lower lameness and severe lameness prevalence than herds that trimmed 1 time (16.8% and 4.7%) or 2 times (21.1% and 5.9%) during lactation with 1 and 2 times being similar. Espejo and Endres (2007) found no differences between hoof trimming 1 or 2 times during lactation, which was in agreement with the findings of this study. The results of the current study indicate that adding a 3rd scheduled hoof trimming during lactation may have beneficial effects on both lameness and severe lameness. However, only 1 herd included in the analysis was practicing hoof trimming 3 times during lactation, and therefore the results may be more related to the overall management of that farm, and not just necessarily the number of times hoof trimming was performed.

Hock Lesions

Hock lesion prevalence was 22.8% and severe hock lesion prevalence was 2.3%. Hock lesion prevalence in this study was less than previously reported in other studies, where prevalence ranged from 42% to 81% (Weary and Taszkun, 2000; von Keyserlingk et al., 2012). As was mentioned previously, 14 of the 15 herds in this study were housed on deep beds, with 1 farm utilizing mattress based freestalls. Both prevalence and severity of lesions have been found to be greater in herds housed on mattress based freestalls when compared to herds using deep bedded sand (Fulwider et al., 2007; Barrientos et al., 2013; Zaffino Heyerhoff et al., 2014) and herds using deep bedded RMS (Husfeldt and Endres, 2012), which may explain to some extent the lower overall prevalence of lesions and severe lesions in comparison to prior studies.

Due to the factors that were discussed, the 1 herd utilizing mattress based freestalls was removed from the analysis for hock lesions and severe hock lesions. Results of the univariate analysis for hock lesion prevalence are found in Table 3 and results of the analysis for severe hock lesion prevalence are found in Table 4. For hock lesion prevalence, breed, bedding type, and bedding frequency per week were included in the initial multivariate model, whereas breed, bedding type, average pen DIM, average pen parity, and bedding frequency per week were included in the multivariate model for severe hock lesions.

Risk factors for hock lesion prevalence (Table 3) were found to be breed ($P = 0.001$) and bedding type ($P < 0.001$), and breed was also associated with severe hock lesion prevalence (Table 4). Within breed, Jersey herds (3.7% and 0.5%) were found to have significantly lower hock lesion and severe hock lesion prevalence than their Holstein (16.7% and 2.1%) counterparts, and were also found to have significantly lower hock lesion prevalence than crossbred herds (15.4%). As Jersey herds accounted for just 2 farms, research with more operations is needed to ensure a confounding effect of overall farm management is not the reason for the decreased hock lesion prevalence.

For bedding type, hock lesion prevalence for cows housed on deep bedded sand freestalls (5.0%) was lower than cows housed in freestalls with deep bedded RMS (19.5%). Studies with sand have found hock lesion prevalence to be near 25% (Weary and Taszkun, 2000; Fulwider et al., 2007), and hock lesion prevalence in herds utilizing deep bedded RMS was 49.4% (Husfeldt and Endres, 2012). While numerically lower for both bedding types, the results of the current study also indicated improvements in hock lesion prevalence with the use of sand bedding. Due to the physical nature of RMS, it is likely it can be more easily packed down by the weight of a cow than sand. This could potentially expose more of the rear curb in the stall and lead to more problems with hock lesions, as was seen in the results of this study.

Mortality and Herd Turnover

Mortality rates appear to be a growing concern across the industry. Work done by the USDA:APHIS:VS National Animal Health Monitoring System (NAHMS) showed an increase in annual mortality rates from 4.8% in their 2002 survey to 5.7% in their 2007 survey (USDA, 2002; USDA, 2007). Mortality rates in the current study averaged 7.4 ± 2.1% across all farms. While alarming, this number agrees with the mortality rate of 7.1% found from farms with more than 500 cows, using DHIA records from 10 Midwestern states (M. Shahid, University of Minnesota, unpublished data), and larger herd size has been identified as a risk factor for mortality (Alvåsen et al., 2012). Of died events recorded on farm, 35.6% occurred within the first 30 DIM, while 44.5% of deaths occurred in the first 60 DIM. Results of other studies on this topic were in agreement with these findings. Hadley et al. (2006) reported that 42% of deaths occurred during the first 60 DIM, and Dechow and Goodling (2008) reported 42% of mortalities occurred from d 0 to d 60 of lactation.

Producer attributed causes for mortalities are found in Table 5. The top reported reason for death among farms was sick, followed by unknown reasons, injury, mastitis, miscellaneous reasons, transition problems, downer cows, lameness, dystocia, and euthanasia. These results indicate improvements can be made in record keeping in the on farm record system regarding identifying reasons for deaths. Sick is a broad category that could encompass a variety of diseases or conditions, and unknown reasons also made up a large percentage of the recorded reasons for death. For this reason, more precise record keeping is needed to accurately identify and monitor what is causing cows to die on farms.

A univariate analysis was performed on mortality rates and results of this can be found in Table 6. Breed, herd size, and the presence of a hoof trimmer on farm were included in the initial multivariate analysis, and breed was found to be the only risk factor associated with mortality (Table 6) in this analysis ($P = 0.015$). Within breed, Jersey herds had lower mortality rates (5.2%) than Holstein (7.4%) and Jersey-Holstein crossbreds (9.8%) counterparts. While these results may indicate advantages with the Jersey breed for mortality rates in these large operations, it should be noted that only 2 Jersey herds and 1 Crossbred herd were represented in the analysis. Therefore, additional research is needed with more herds to determine if breed is in fact associated with mortality in large Midwest dairy systems.

Culling is the departure of cows from a herd due to sale, slaughter, salvage, or death, and describes the percentage of cows removed from a herd (Fetrow et al., 2006). Rogers et al. (1988) suggested that a turnover rate of 25% is optimal; however, there is no percentage that is standard or optimal for a dairy. This is because culling decisions are an economic comparison of the current cow to her potential replacement (Hadley et al., 2006), and therefore should be a dynamic decision based on individual farm goals while also considering future implications of the culling decision (Fetrow et al., 2006; Hadley et al., 2006).

Average herd turnover rate for across all operations was 41.6 ± 5.9% with a range of 33.9% to 55.3%. Turnover in the first 30 DIM and 60 DIM accounted for 15.1% and 22.2% of all turnover, respectively. Producer attributed sold reasons are found in Table 7. Low production was the top reason for selling an animal, followed by mastitis, sick, unknown reasons, lame, reproduction, miscellaneous reasons, abortion, udder conformation, and transition problems. As low production accounted for 30% of all sold reasons, this represents a large portion of cows that were culled voluntarily from these large operations, whereas NAHMS 2007 (part I) found reproduction and udder or mastitis problems to be the most prominent reason for removal of cows among US dairy operations.

Mastitis Incidence

Incidence rates of clinical mastitis in the current study averaged 62.5 ± 31.7 cases per 100 cow-years and ranged from 10.5 to 118.5 cases per 100 cow-years. Incidence rates in this study were greater than the 22.8 cases per 100 cow-years found in a study of

1,800 British dairy farms (Peeler et al., 2000) and 23.0 cases per 100 cow-years found in a study of 106 dairy farms in Canada (Olde Riekerink et al., 2008). Husfeldt and Endres (2012), however, found incidence rates of clinical mastitis to be 66.3 in Midwest freestall based systems using deep bedded RMS, which is similar to what was found in the current study. Peeler et al. (2000) noted that variation in factors such as environment, facilities and housing, and management practices are associated with mastitis, and may explain some of the variation seen across these other studies and the current study.

Table 8 shows the results of the univariate analysis of variables and their association with clinical mastitis incidence. All farms were included in this analysis, and breed, bedding type, and bedding frequency were included in the initial multivariate model. From this model, risk factors for mastitis incidence (Table 8) on these large dairies were found to be breed ($P = 0.047$) and bedding type ($P = 0.011$). Within breed, Jersey herds were found to have lower ($P = 0.018$) mastitis incidence (33.0 cases per 100 cow years) than Holstein operations (73.2 cases per 100 cow years), and also tended ($P = 0.055$) to have lower mastitis incidence than Crossbred farms (83.4 cases per 100 cow years).

Within bedding type, farms that utilized sand as a bedding surface were found to have lower (P = 0.011) incidence of clinical mastitis (49.0 cases per 100 cow years) than farms that utilized RMS as a bedding surface (77.3 cases per 100 cow years). Differences in mastitis incidence and bedding type in the current study likely exist due to sand being an inorganic bedding material, whereas RMS are organic. Hogan et al. (1989) found inorganic bedding materials to have significantly lower bacterial counts than organic bedding materials. A number of studies have found relationships between the number of bacteria in the bedding and the number of bacteria on the teat end of a cow (Rendos et al., 1975; Hogan et al., 1989; Zdanowicz et al., 2004), and high bacterial levels on the teat end resulted in increased incidence of environmental mastitis (Hogan et al., 1989). Currently, most cases of clinical mastitis on farms have been found to be caused by environmental pathogens (Oliveira et al., 2013). Therefore, proper management of all aspects of the farm affecting milk quality, especially bedding management, is particularly important in the control of mastitis in modern dairy operations.

Conclusions

With the trend for increasing farm size, understanding how these facilities operate will be vital as more large operations move into the Midwest. Various management practices utilized on these farms have been discussed, and preliminary risk factors for several welfare characteristics on these farms have been identified. Lameness prevalence and severe lameness prevalence appear to be similar to that found in other recent studies of larger freestall systems, and the presence of an on-farm hoof trimmer and increased trimming frequency were associated with lower lameness prevalence in these very large operations. While overall hock and severe hock lesion prevalence appear to be lower than what has been reported in past work, Jersey herds were found to associated with lower overall hock and severe hock lesion prevalence, and herds that utilized sand bedding were found to be associated with lower overall hock lesions. Mortality rates were found to be in agreement with recent trends for mortality in large dairy operations, and Jersey herds were also found to be associated with lower mortality rates when compared with Holstein and Crossbred counterparts. Clinical mastitis incidence across all farms was found to be higher than what has been previously reported. Jersey herds were associated with lower clinical mastitis incidence, and there was also found to be associations between sand bedding and lower mastitis incidence when compared to farms utilizing RMS as a bedding source. While these risk factors may suggest that certain breeds, bedding types, or management practices may help to optimize welfare on very large operations in the Midwest, more research is needed with a larger number of herds and more explanatory risk factor variables before definitive conclusions can be made in regards to management decisions that provide optimal welfare on these large dairy operations.

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Table 1. Regression analysis probability values between lameness prevalence (locomotion score ≥ 3 on a 1-5 scale) and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with lameness prevalence in dairies with more than 2,500 cows in the Upper Midwest.

Univariate Analysis	
Variable	*P*-Value
Barn Type	0.45
Bedding Type	0.18
Breed	0.01
Avg. Pen DIM	0.18
Avg. Pen Parity	0.95
Hoof Trimmer on Farm	0.08
Hoof Trimming Frequency	0.001
Trimming Frequency*Bedding Type	0.01

Multivariate Analysis			
Variable	LSMeans (%)	95% CI	*P*-Value
Hoof trimmer on farm			0.02
Yes	11.3	9.3 – 13.8	
No	16.0	12.2 – 20.9	
Hoof trimming frequency			<0.001
1	16.8^{a}	13.6 – 20.8	
2	21.1^{a}	17.6 – 25.2	
3 or greater	6.9^{b}	4.2 – 11.2	

LSMeans with different superscripts differ (P < 0.05)

Table 2. Regression analysis probability values between severe lameness prevalence (locomotion score ≥ 4 on a 1-5 scale) and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with severe lameness prevalence in dairies with more than 2,500 cows in the Upper Midwest

Univariate Analysis			
Variable		*P*-Value	
Barn Type		0.65	
Bedding Type		0.21	
Breed		0.03	
Avg. Pen DIM		0.26	
Avg. Pen Parity		0.81	
Hoof Trimmer on Farm		0.16	
Hoof Trimming Frequency		0.002	
Trimming Frequency*Bedding Type		0.01	
Multivariate Analysis			
Variable	LSMeans (%)	95% CI	*P*-Value
Hoof trimming frequency			0.002
1	4.7^{a}	3.5 – 6.4	
2	5.9^{a}	4.6 – 7.5	
3 or greater	1.5^{b}	0.8 – 3.0	

LSMeans with different superscripts differ (P < 0.05)

Table 3. Regression analysis probability values between hock lesion prevalence (hock score ≥ 2 on 1-3 scale) and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with hock lesion prevalence in dairies with more than 2,500 cows in the Upper Midwest

Univariate Analysis			
Variable		*P*-Value	
Barn Type		0.71	
Bedding Type		0.07	
Breed		0.002	
Avg. Pen DIM		0.73	
Avg. Pen Parity		0.45	
Bedding Frequency		0.01	
Multivariate Analysis			
Variable	LSMeans (%)	95% CI	*P*-Value
Breed			0.001
Holstein	16.7^{a}	11.9 – 23.5	
Jersey	3.7^{b}	1.9 – 7.2	
Crossbred	15.4^{a}	6.0 – 39.2	
Bedding Type			<0.001
Sand	5.0	3.2 – 7.9	
RMS	19.5	11.4 – 33.2	

LSMeans with different superscripts differ (P < 0.05)

Table 4. Regression analysis probability values between severe hock lesion prevalence (hock score = 3 on a 1-3 scale) and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with severe hock lesion prevalence in dairies with more than 2,500 cows in the Upper Midwest

Univariate Analysis			
Variable	*P*-Value		
Barn Type	0.97		
Bedding Type	0.11		
Breed	0.01		
Avg. Pen DIM	0.60		
Avg. Pen Parity	0.09		
Bedding Frequency	0.15		
Multivariate Analysis			
Variable	LSMeans (%)	95% CI	*P*-Value
Breed			0.01
Holstein	2.1^{a}	1.5 – 2.9	
Jersey	0.5^{b}	0.3 – 1.1	
Crossbred	1.3^{ab}	0.4 – 4.6	

LSMeans with different superscripts differ (P < 0.05)

Table 5. Producer attributed causes for mortality as reported in on-farm record systems[1]

Died Event Category	Mean	S.D.
Sick	33.5	17.4
Unknown	15.4	24.6
Injury	11.1	10.6
Mastitis	9.9	8.5
Miscellaneous	8.4	4.9
Transition Problems	7.4	5.8
Down Cow	5.6	12.3
Lameness	5.2	5.5
Dystocia	2.1	1.8
Euthanasia	1.4	4.6

[1] Results expressed as percent of the total number of cows that died

Table 6. Regression analysis probability values between mortality rate and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with mortality rate in dairies with more than 2,500 cows in the Upper Midwest

Univariate Analysis			
Variable		*P*-Value	
Barn Type		0.39	
Bedding Type		0.89	
Breed		0.02	
Herd Size		0.19	
Mastitis Incidence Rate		0.66	
Hoof Trimmer on Farm		0.30	
Cows / Employee		0.54	
Multivariate Analysis			
Variable	LSMeans (%)	95% CI	*P*-Value
Breed			0.015
Holstein	7.4^{a}	6.6 – 8.2	
Jersey	5.2^{b}	4.0 – 6.7	
Crossbred	9.8^{a}	6.7 – 14.1	

LSMeans with different superscripts differ (P < 0.05)

Table 7. Producer attributed reasons for culling as reported in on-farm record systems[1]

Sold Event Category	Mean	S.D.
Low Production	30.0	22.0
Mastitis	16.4	11.9
Sick	12.7	5.2
Unknown	8.6	21.3
Lame	8.5	4.9
Reproduction	8.1	10.5
Miscellaneous	7.2	5.4
Abortion	3.4	5.6
Udder Conformation	2.7	2.1
Transition Problems	2.5	3.1

[1] Results expressed as percent of the total number of cows that were sold

Table 8. Regression analysis probability values between clinical mastitis incidence and farm-level variables, and farm-level variables and least squares means of qualitative factors associated with clinical mastitis incidence in dairies with more than 2,500 cows in the Upper Midwest

Univariate Analysis	
Variable	*P*-Value
Barn Type	0.70
Bedding Type	0.02
Breed	0.10
Bedding Frequency	0.22
Hygiene	0.38

Multivariate Analysis			
Variable	LSMeans (Cases/100 cow years)	SE	*P*-Value
Breed			0.047
Holstein	73.2^{a}	9.8	
Jersey	33.0^{b}	13.5	
Crossbred	83.4^{ab}	21.8	
Bedding Type			0.011
Sand	49.0	10.7	
RMS	77.3	12.3	

LSMeans with different superscripts differ (P < 0.05)

CHAPTER 3:

Economics and operational characteristics of large dairy operations in the Upper Midwest U.S.

OVERVIEW

Dairy farming has been shifting to fewer, larger farms. This trend has also been observed in the Upper Midwest, where small farms have historically dominated the region. The share of milk production from farms with more the 500 cows has greatly increased, and a significant share of milk production in the region now comes from farms with more than 2,500 cows. The objective of this cross-sectional study was to describe cost of production, and characterize labor and operational structure of farms with more than 2,500 cows in the Upper Midwest. The study included 15 commercial dairy operations in Minnesota, Wisconsin, Iowa, and South Dakota. All operations had over 2,500 lactating cows in a freestall system, and average herd size was 4,972 cows. Twelve of the farms had Holstein cows, 2 farms had Jersey, and 1 farm had Jersey x Holstein crosses. Farms were visited twice in July or August of 2012 and 2013, and information about farm operations and labor were collected from on-farm interviews. Farms were also contacted to provide cost of production information and milk production data for the year ending December 31, 2012. Cost of production averaged \$17.88 per hundredweight of milk produced (**cwt**), and net income averaged \$1.47/cwt. By category, feed costs were the highest at \$9.47/cwt, followed by labor at \$1.90/cwt, interested and depreciation at \$1.76/cwt, and replacement costs at \$1.70/cwt. Average land required for forage production was 0.65 acres per cow, while average land required for manure application was 0.85 acres per cow. All 15 operations utilized primarily hired labor in the form of non-US born immigrants. Very large dairies in the Upper Midwest appear to have been highly profitable; however, with feed costs being the largest cost to producing milk, the effects of commodity market volatility must be closely monitored. Also, with a heavy reliance on hired immigrant labor, future policy related to immigration may have significant industry-wide effects on labor supply.

INTRODUCTION

Recent trends in the structure of the dairy industry have shown dramatic decreases in the number of farms, while average farm size continues to get larger. Blayney (2002) described the influence that technological innovation, changes in the milk production system, and specialization has had on this changing farm structure over the past decades. These factors, combined with financial advantages realized by producers in taking advantage of economies of scale, are the main driving forces behind the consolidation of the dairy industry (MacDonald et al., 2007).

While large dairies are thought to exist primarily in Western States, the Upper Midwest has shown recent growth in the share of milk production that is produced on large farms. From 2000 to 2012, the percent of state milk production coming from farms with more than 500 head increased nearly threefold in Minnesota, Iowa, South Dakota, and Wisconsin; from 8.5 to 32.6% in Minnesota, 5.0 to 44.1% in Iowa, 26.0 to 75.2% in South Dakota, and 9.0 to 38.1% in Wisconsin (USDA, 2001; USDA, 2014). Very large operations (>2,500 cows) have also begun to take hold in the region. In 2012, these operations accounted for just 0.2% of the total number of operations in these states, but were responsible for over 11% of total milk production that occurred in the four-state region mentioned earlier (USDA, 2014).

In recent years, market volatility in the areas of milk sales and feed costs has put profitability at the forefront of the dairy industry (Dhuyvetter, 2011). One tool used by producers to monitor profitability is cost of production. Components of cost of production include operating costs, such as feed, labor, replacement costs, veterinary expenses, bedding, repairs, fuel, and utilities, as well as ownership costs, which includes depreciation and interest on dairy facilities and equipment (Short, 2004, USDA). Economies of scale within the dairy industry refer to a realized decline in average cost of production due to a more efficient allocation of labor, capital, and management (Wolf, 2003). Scale economies incentivizes farms to increase in size, and farms with 1,000 cows or more were found to have lower operating costs and overhead costs, and higher net returns than any other size class (MacDonald et al., 2007). Along with this, Bailey et al. (1997) found that in an economic simulation study of 150-, 300-, 500-, and 1000-cow startup dairies in the Midwest, only the 500- and 1000-cow units would be economically viable.

Coinciding with the changes in farm size have been changes in the labor structure within dairy farms. Specialization within the industry shifted milk production from a sideline activity on a farm to the sole or most important activity, and farmers shifted from being a do-it-all type of worker to one that specialized in certain areas of the farm, such as financial or labor management (Blayney, 2002). With increasing farm sizes, reliance on hired labor, particularly immigrant labor, has become extremely important. It is estimated that over 60% of the nation's milk supply come from farms that utilize immigrant labor (Rosson et al., 2009).

Currently, little research exists regarding large dairy farms currently in operation in the Upper Midwest. Specifically, as very large farms (>2,500 cows) continue to show up in the region, understanding both the economic and labor structure of these operations will become increasingly important. Therefore, the objective of this study was to describe cost of production, and characterize labor and operational structure of farms with more than 2,500 cows in the Upper Midwest.

MATERIALS AND METHODS

This cross-sectional observational study was conducted between July 2012 and August 2013 on 15 large dairy operations in the Upper Midwest. Herds were selected on the basis that they had more than 2,500 lactating cows, utilized freestall housing, and had been in operation or under current management for a period of at least one year prior to our first visit. No other constraints were included in an effort to maximize sample size. Operations were identified through extension educators, industry personnel, and other producers. Following the identification process, producers were contacted to confirm the selection criteria and to obtain consent to participate in the study.

Data Collection

Each operation in the study was visited twice during the study period to perform on-farm data collection. The first visit was conducted between July and October of 2012, with a follow up visit between July and August of 2013. Records were obtained from the on-farm herd management software and on farm interviews were conducted with herd managers or owners to obtain information regarding farm information, on-farm management practices, and organizational structure using a 25 question survey. Daily bulk tank information was obtained for January to December 2012, when accessible, from each herd's processor.

Farms were also contacted at the end of 2012 to obtain cost of production information for the 12-mo period ending on December 31, 2012. Revenues were reported for milk sales and other sales. Categories for the reporting of expenses were replacement costs; labor; feed; bedding; repairs; supplies; fuel, oil, and grease; breeding costs; hoof care; veterinary service and supplies; manure pumping and handling; utilities; taxes and insurance; interest and depreciation; and other costs. Net income was reported as total sales minus total expenses. Costs per hundredweight of milk sold (**cwt**) of each line item were calculated by dividing the total value of the itemized sale or expense by the pounds of milk shipped, which was then divided by 100 to convert it to CWT. Information for total pounds of milk shipped was received from daily bulk tank information.

Profitability Groups

Farms were grouped by the top 50% and bottom 50% of farms for profitability. Statistics relating to farm level characteristics were described for each group for: net income, mortality rate, herd turnover rate, pregnancy rate, mastitis incidence rate, milk production per employee, and number of cows per employee.

Mastitis Incidence. Mastitis incidence for each herd was calculated as the number of cases of mastitis per 100 cow-years at risk. This analysis was done for two 1-

yr periods from July 2011 to July 2013. The number of mastitis cases and the number of cows at risk were obtained from each farm's on farm record system. Number of cows at risk during the year was calculated as the average of the weekly lactating herd size, as reported in the on-farm record system. Reported clinical mastitis cases were considered to be a new case if more than 14d had passed between the previous and current case of clinical mastitis (Barkema et al., 1998).

Culling and Mortality. Information on culling and mortality was also collected from the on-farm record keeping system, and analyzed over the 2-yr period from July 2011 to July 2013. Turnover rate was calculated as the number of animals that left the dairy (sold or died) over the course of each 1-yr period divided by the average weekly herd inventory during that period (Fetrow et al., 2006). The percentage of culling during the first 30 and first 60 DIM was calculated by dividing the number of animals that were sold or died during the first 30-d and 60-d of lactation in a 1-yr period divided by the total number of animals that were sold or died during that same period.

Mortality rate was calculated as the number of animals that died during a 1-yr period, divided by the average herd size during that period. Mortality during the first 30-d and 60-d of lactation, as a percent of total deaths, were calculated by dividing the number of cows that died during the first 30-d and 60-d of lactation during each 1-yr period by the total number of cows that died during each 1-yr period.

Pregnancy Rate. Pregnancy rate was monitored on each farm over the 2-yr period utilizing the on-farm record system. Overall pregnancy rate was calculated as the number of cows that became pregnant divided by the number of cows at risk of becoming pregnant in a 21-d period. An overall average of pregnancy rate for each 21-d period in the 2-yr study period was used for analysis.

Statistical Analysis

The MEANS procedure (SAS Institute Inc. Cary, NC) was used to report average overall costs and costs per hundredweight of milk produced, along with average farm level information consisting of herd size, production data, and data regarding the average amount of land needed per cow for feed production and manure application. This procedure was also used to report averages for net income per cwt, mortality rates, turnover rates, pregnancy rates, mastitis incidence, milk production per employee, and number of cows per employee for the top 50% and bottom 50% of farms for profitability.

RESULTS AND DISCUSSION

Herd Characteristics

Farms were located in Wisconsin (6), Minnesota (5), Iowa (3), and South Dakota (1). In terms of breed composition, 12 of the operations had Holstein, 2 had Jersey, and 1 had predominantly Holstein and Jersey crosses. Seven of the operations housed cows in freestalls with deep bedded sand, 7 operations utilized deep bedded recycled manure solids (**RMS**), and 1 farm utilized RMS in a 2-3 inch layer on top of mattress based freestalls. Eight of the farms housed the majority of cows in mechanically ventilated (i.e. cross ventilated or tunnel ventilated) freestall barns, whereas 7 farms housed cows in naturally ventilated freestall barns. Average herd size (mean ± SD) across all farms was 4,972 ± 2,652 cows with a range from 2,606 to 13,266. Annual bulk tank records were obtained from 12 of the participating farms. Daily energy-corrected milk (ECM) production per cow based on milk sold was 31.9 ± 3.3 kg. Milk fat content was 3.85 ± 0.32% and milk protein content was 3.15 ± 0.17. Bulk tank somatic cell count (BTSCC) was 190,250 ± 37,860 cells/ml.

Economic Characteristics

Of the 15 farms participating in the study, 9 farms agreed to provide financial information regarding cost of production. From the 9 farms, 1 operation was excluded from the analysis after the data provided was deemed unusable. A summary of total sales, total costs, and net income for each of the remaining farms is found in **Figure 1**. Of these 8 farms, 1 operation reported sales and costs associated with all farm ventures, accounting for the relatively higher price per hundredweight of milk produced in total sales and total costs for Farm E. For this reason, only line items related solely to the dairy enterprise were analyzed using all 8 farms. These consisted of feed costs, replacement costs, bedding costs, breeding costs, veterinary costs and hoof care costs. All other categories were analyzed using the final 7 operations.

Table 1 shows the average cwt and line item totals across all farms included in the final analysis. In 2012, the average price received for milk was $19.02/cwt and total sales averaged $19.35/cwt. Milk price received was slightly higher than the industry average of $18.52/cwt for 2012 (Gould, 2012). Total expenses averaged $17.88/cwt, leaving an average net income of $1.47/cwt. Income per cow was $405.94, and ranged from $57.71 up to $611.66. Within farm expenses, feed costs accounted for the greatest cost to producers at $9.47/cwt, and includes both purchased and homegrown feed at market value. This was followed by labor at $1.90/cwt, interest and depreciation expenses at \$1.76/cwt, and replacement costs at \$1.70/cwt. Feed, labor, and replacement costs are generally regarded as the 3 greatest costs on a dairy farm, and this was observed, for the most part, in the current study. However, interest and depreciation expenses were also quite high, and high capital recovery costs suggest costly initial investments in the dairy operation.

In looking closer at overall costs on these operations, feed costs accounted for roughly 53% of the total cost of producing milk in the current study. This cost is roughly 5 times greater than that of labor costs, the next most costly part of producing milk. This exemplifies how slight changes in not only milk prices, but commodity markets related to feed inputs can have such a significant impact on the cost to produce. Bailey (2007) reported that feed costs account for anywhere from 40-60% of the cost of producing milk, so the value found in the current study falls in line with that suggestion. The University of Minnesota Center for Farm Financial Management (FINBIN, 2012) dairy report had an average feed cost of \$10.33/cwt for 469 dairy farms that were included in their data set. Farms in that report were located in Minnesota, Wisconsin, and South Dakota, and average herd size was 166 cows. However, for the 26 farms in their data set with more than 500 cows, feed costs were \$9.63 cwt, which were similar to the findings of the current study. It was also noticed in the FINBIN report that feed costs per hundredweight of milk produced decreased with each increase in the size category of farm, implying a possible advantage in the efficiency of milk production on larger operations.

Profitability and Herd Characteristics

Results from the analysis of quantitative herd characteristics for herds in the top 50% for profitability relative to herds in the bottom 50% are found in **Table 2**. Herds in the top 50% had a net income of $2.39/cwt relative to $0.95/cwt for herds in the bottom 50%. Herds in the bottom 50% for profitability had lower values for mortality rate (7.9% vs. 8.6%) and mastitis incidence rate (57.4 cases/100 cow years vs. 60.0 cases/100 cow years) than herds in the top 50%. It was also found that the lower profitability herds also had lower values for the percent cow deaths on farm that occurred before 30 DIM (33.7% vs. 37.3%) and before 60 DIM (41.5% vs. 47.6%). These herds also had lower values for the percent of turnover that occurred before 30 DIM (13.5% vs. 16.3%) and before 60 DIM (20.7% vs. 23.6%). Farms in this category also fed a larger number of rations (8.0 vs. 5.5).

Farms in the top 50% for profitability showed advantages in feed costs/cwt ($9.22 vs. 9.71) overall turnover rates (36.2% vs. 41.0%), lameness prevalence (16.8% vs. 20.5%), pregnancy rate (26.2% vs. 20.8%), pounds of milk sold per employee, and the number of cows per employee. As was mentioned previously, feed costs make up the largest portion of the cost of producing milk, so it should come as no surprise that higher profitability farms had a numerically lower feed costs than the lower profitability farms. Aside from feed costs, however, labor and replacement cost make up the next largest portion of the cost of producing milk.

The higher profitably farms also had advantages in turnover rates and measures of labor efficiency, such as milk sold per employee and number of cows per employee.

Lower turnover rates would likely results in lower overall replacement costs due to not having to replace as many cows that had to be sold or died with heifers that would need to be raised or purchased by the farm. This was, in fact reflected in the replacement costs, as farms in the top 50% had replacement costs of $1.40/cwt, while replacement costs for farms in the bottom 50% were $2.00/cwt. Improvements in labor efficiency would likely result in improvements in labor costs. This was also observed between the 2 groups, as higher profitability farms had lower ($1.84/cwt) labor costs than the lower profitability farms ($1.98/cwt).

Results of qualitative management characteristics are found in **Table 3**. Barn type, breed composition, and the number of farms employing an on farm hoof trimmer appear to be similar in their distribution for farms in each of the profitability groups that agreed to participate in this portion of the study. However, there appear to be differences in the distribution of farms in the category of bedding type along with operating a digester. All farms in the top 50% for net income/cwt utilized RMS to bed cows, whereas the bottom 50% of farms included 3 farms that utilized sand and 1 that bedded with RMS. This brings up the idea of possible cost advantages realized with the use of RMS due to not having to invest in costly manure handling systems or additional wear and tear on commitment that is commonly seen with sand bedding. Along with this, 3 of the 4 farms in the top 50% of farms for profitability operated a digester, whereas no farms operated a digester in the bottom 50%. This is likely tied to the fact that digesters are more commonly used in farms that utilize RMS for bedding, and in the current study all of the more profitable farms housed cows on RMS.

Land

Land is an important resource for dairy operations in regards to supplying feed for the cows to consume along with providing an area to deposit manure, which can be used as a natural fertilizer. In the current study, 10 operations provided information regarding how feed was secured for the operation, along with land requirements for both feed production and manure application. One farm had to be excluded from the analysis due to incomplete information regarding land for feed production. For feed production, which consisted of primarily corn silage and alfalfa haylage, the average land requirement per cow was 0.65 ± 0.07 acres. For the operations participating in this portion of the study, all utilized their own machinery to harvest forages on land that was either owned by the dairy or through harvesting contracts with other land owners. Aside from these forages, the dairies reported that all other feedstuffs included in rations were purchased.

Land for manure application averaged 0.85 ± 0.45 acres per cow with a range from 0.63 to 2.01 acres per cow. The great disparity between values is likely due to differences in location among the operations. Although all operations were located in the Upper Midwest, nutrient content of the land near each of the dairy operations likely varied greatly. This would have a significant impact on the amount of manure that could be applied to the land based on crop nutrient requirements and state regulations regarding manure application.

Labor

The number of employees on each operation was 48.5 ± 31.2, with a range of 27 to 155. From this, milk sold per employee was 1,120,745 ± 180,472 kg, and the number of cows per employee was 105.1 ± 21.6. All 15 operations included in the study utilized outside hired labor, with the majority of employees being non-US born immigrants. Rosson et al. (2009) found in a nationwide survey that 41% of farms rely on hired labor from immigrant employees, so it is apparent that these employees are particularly important to larger herds, where more hired labor is needed. Susanto et al. (2010) found in a survey of over 5,000 dairy herds that expected labor shortages in the future as a result of immigration policy increased the probability of a dairy operation exiting the industry by 10%. From this, the larger the herd size the more likely they were to indicate their intention to exit. This substantiates the importance of immigrant labor for large dairy operations.

The organization of labor was found to be similar in structure across all dairies participating in the study. Most commonly, there was a general manager present that would oversee all operations. Under the general manager was the head herdsman, who was sometimes referred to as an assistant manager depending on the operation. Their primary duty was to oversee the operations inside the dairy. Under the head herdsman were leads in different areas within the dairy. Generally, the main areas consisted of feeding and nutrition, maternity, reproduction, hospital and treatments, and the milking parlor. Under the leads in each of the areas were general laborers, and the number of general laborers in each area varied depending on the task that each area needed to accomplish. For example, a higher number of general laborers would be needed in the parlor to milk the cows than would be needed in the feeding/nutrition area to operate a feed truck and mix rations.

CONCLUSIONS

As more large farms move into the Upper Midwest, being able to characterize their economic efficiency and operational structure will be important in ensuring their sustainability, both from an economic and social standpoint. The results of this study indicate very large farms in this region are profitable. However, volatility in the commodity markets could have significant effects on profitability, as both the milk price received and feed costs are such a large component of this measure. It has also been established that these large operations are highly structured in terms of their labor force. As all of the farms in this study rely on hired labor, which consists largely of non-native born employees, future implications regarding immigration policy could have dramatic effects on labor supply industry wide.

Economic Model Development

Data from this study are from a larger project looking to characterize not only the economics and organizational structure of very large dairy operations in the Upper Midwest, but also their common management practices and welfare characteristics. This was done through a combination of on-farm scoring, farm record evaluation, and producer questionnaires. Future work will include the development of a model as a tool for current producers, or those looking to construct a large dairy, to use in making decisions as to optimal farm characteristics and management strategies under varying market conditions. It is our goal that these farms can be used as case studies in developing the model to provide real world data for the basis of its construction.

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Figure 1. Total sales, costs, and net income per hundredweight of milk produced in 8 dairy operations with more the 2,500 cows in the Upper Midwest.

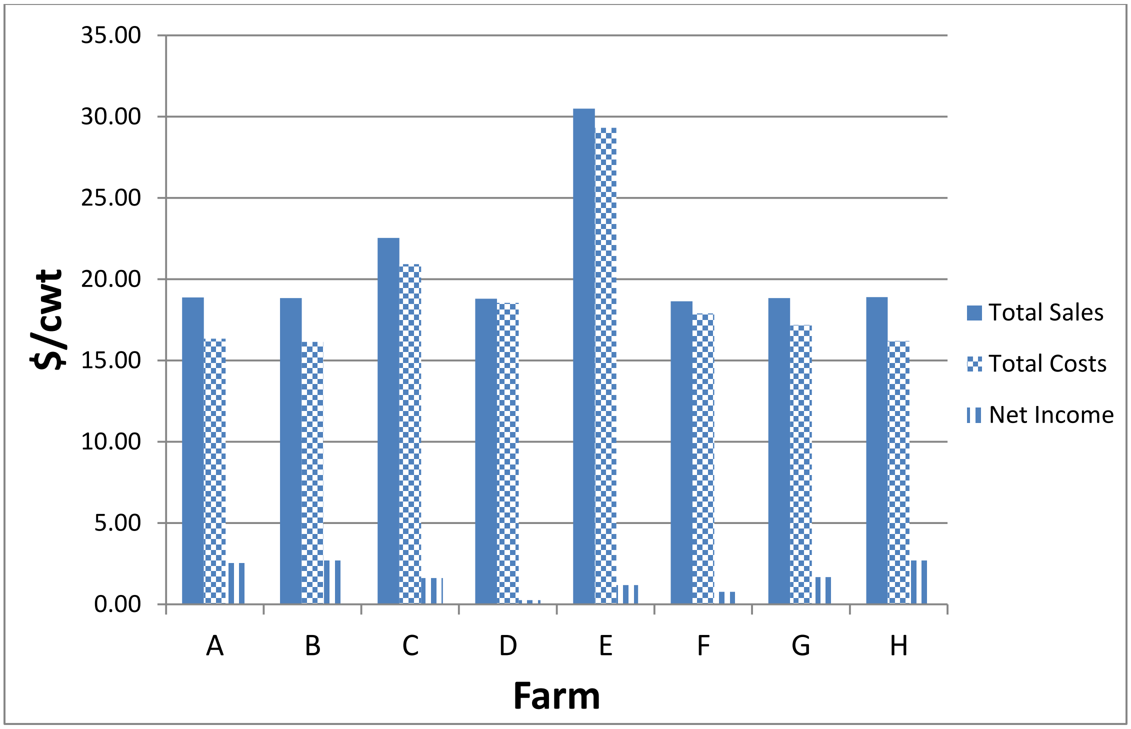

Table 1. Average gross sales and costs, and sales and costs per hundredweight of milk sold (CWT) for operations with more than 2,500 cows in the Upper Midwest.

	Total ($)	CWT ($)	Range
Sales			
Milk	29,406,648	19.02	18.45 - 21.05
Other	432,196	0.33	0.04 - 1.49
Total Sales	29,838,844	19.35	18.65 - 22.54
Costs			
Feed	13,661,975	9.47	8.76 - 10.15
Labor	3,101,846	1.90	1.52 - 2.42
Replacement	2,248,597	1.70	1.22 - 2.88
Bedding	15,130	0.02	0.00 - 0.09
Repairs	567,464	0.38	0.28 - 0.56
Supplies	564,044	0.35	0.25 - 0.38
Fuel, Oil, and Grease	424,252	0.25	0.19 - 0.38
Breeding: Semen and/or Service	178,388	0.13	0.07 - 0.27
Hoof Care	97,156	0.07	0.05 - 0.13
Veterinary: Service and Medication	505,420	0.34	0.26 - 0.53
Manure Pumping and Handling	370,095	0.24	0.09 - 0.41
Utilities	646,916	0.37	0.31 - 0.59
Taxes and Insurance	246,831	0.18	0.12 - 0.46
Depreciation and Interest	2,699,875	1.76	1.34 - 2.30
Other	1,114,874	0.72	0.26 - 1.78
Total Costs	26,442,863	17.88	16.15 - 20.93
Net Income	3,395,981	1.47	0.26 - 2.70

Table 2. Quantitative characteristics of farms in the top 50% and bottom 50% of operations for net income per hundredweight of milk sold.

Variable	**Top 50%**	S.D.	**Bottom 50%**	S.D.
Net Income ($/cwt)	2.39	0.49	0.95	0.58
Feed Costs ($/cwt)	9.22	0.33	9.71	0.54
Labor Costs ($/cwt)	1.84	0.27	1.98	0.45
Replacement Costs ($/cwt)	1.40	0.16	2.00	0.74
Mortality Rate (%)	8.6	2.5	7.9	1.8
Died < 30 DIM (%)	37.3	5.4	33.7	4.6
Died < 60 DIM (%)	47.6	3.9	41.5	5.9
Herd Turnover Rate (%)	36.2	1.3	41.0	4.4
Turnover < 30 DIM (%)	16.3	3.3	13.5	2.5
Turnover < 60 DIM (%)	23.6	3.3	20.7	4.1
Pregnancy Rate (%)	26.2	1.6	20.8	4.8
Lameness Prevalence (%)	16.8	10.2	20.5	8.5
Mastitis Incidence Rate (cases/100 cow years)	60.0	21.5	57.4	20.6
Number of Rations Fed	5.5	1.7	8.0	1.6
Milk Sold/Employee (lbs)	2,824,355	372,205	2,327,371	622,838
Cows/Employee	122	20	92	32

Table 3. Qualitative characteristics of farms in the top 50% and bottom 50% of operations for net income per hundredweight of milk sold.

Variable[1]	**Top 50%**	**Bottom 50%**
Barn Type		
Mechanically Ventilated	3 (75%)	3 (75%)
Naturally Ventilated	1 (25%)	1 (25%)
Bedding Type		
RMS	4 (100%)	1 (25%)
Sand	0 (0%)	3 (75%)
Breed		
Holstein	3 (75%)	3 (75%)
Jersey	1 (25%)	0 (0%)
Crossbred	0 (0%)	1 (25%)
Methane Digester		
Yes	3 (75%)	0 (0%)
No	1 (25%)	4 (100%)
Hoof Trimmer on Farm		
Yes	4 (100%)	3 (75%)
No	0 (0%)	1 (25%)

[1] Results of herd characteristics presented as the number of operations utilizing the specified management characteristic.

CONCLUSIONS

Understanding how large dairy farms operate, and characterizing various aspects of animal welfare and the economic structure of these operations, will become increasingly important as more farms of this type move into the Upper Midwest. The objectives of this study were to characterize management practices, animal welfare, and economics on dairy operations with more than 2,500 cows in the Upper Midwest. This was able to be accomplished using data collected from a case study of farms in the aforementioned size category. Aside from descriptive characteristics, an analysis of risk factors related to cow health and welfare were performed to identify possible management characteristics associated with more optimal health and welfare. Along with this, characteristics of more profitable farms were compared with those of less profitable farms to explore possible differences within farm characteristics that may affect profitability. While results of this study are a great first step in working to understand how large dairy systems operate in the Upper Midwest, more research is still needed with a larger number of farms and wider variety of management systems to more accurately identify management systems and factors within these systems that promote optimal welfare and profitability.

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